

**SHIPPING AND NITROGEN TONING EFFECTS ON POSTHARVEST SHELF
LIFE OF VEGETATIVE ANNUALS**

A Thesis

by

SHANNON ELIZABETH BEACH

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2005

Major Subject: Floriculture

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Approved by:

Chair of Committee,	Terri W. Starman
Committee Members,	Kevin M. Heinz
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ABSTRACT

Shipping and Nitrogen Toning Effects on Postharvest

Shelf Life of Vegetative Annuals. (August 2005)

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Chair of Advisory Committee: Dr. Terri Starman

Vegetative annuals are currently popular in the ornamental horticulture industry. Many crops are newly domesticated species and little is known about how they perform during shipping or in the retail environment. Nine species and 21 cultivars were grown and underwent simulated shipping after harvest or nitrogen toning two weeks before harvest. Shipping was not found to affect the number of flowers on all but two cultivars post ship. Nitrogen toning affected vegetative growth of most *Bracteantha bracteata* (bracteantha) cultivars at harvest. All species had an effect due to toning postharvest. Bractenatha and *Diascia ×hybrida* (diascia) were chosen for further study due to their performance during these experiments. The effect of thidiazuron (TDZ) as a foliar spray and nitrogen toning on leaf yellowing and plant growth of bracteantha were evaluated. The two treatments were then combined to see how the two treatments worked together. It was found TDZ decreased leaf yellowing but its effects can be negated if the plants were not toned. Nitrogen toning reduced vegetative growth of the bracteantha without affecting the number of flowers on the plants. Diascia was found to have flower abscission in response to shipping. Further trials were conducted using 1-methylcyclopropene (1-MCP) an ethylene inhibitor. The effects of shipping duration

and temperature were investigated. 1-MCP was found to hold flowers on treated plants longer postharvest than those not treated. Plants shipped for one day had no differences from the control but shipping for two days had a negative effect on plant quality. Postharvest shelf life was decreased when diascia was shipped at 24 °C when compared to cooler shipping temperatures. These results indicate shipping for no longer than one day and at less than 24 °C is recommended for diascia.

DEDICATION

I would like to dedicate this thesis to my mother. She has been a wonderful role model throughout my life. Her selflessness and drive encouraged me when things got rough.

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CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

Introduction

Vegetative annuals are plants propagated vegetatively and sold to the consumer as an annual, whether as a bedding plant or for container use. They are becoming increasingly popular in the floriculture industry because they offer something new and different to consumers. Quality of vegetative annuals is relatively easy to maintain during production because propagative material is virus indexed and stock plants are grown uniformly (Henne, 2002). Vegetative annuals are sold by the grower to retail florists, garden centers and big chain stores. Many of the more unusual species of vegetative annuals are sold to higher-end retailers who expect to receive a high quality plant.

Plant quality is affected by many production factors. These include temperature, light, nutrition, and water. Plant growth regulators and pesticides can also affect plant quality and longevity. Growers can produce high quality potted plants but by the time some species reach the merchant there is a noticeable decrease in quality. Exposure to

This thesis follows the style of the Journal of American Society of Horticultural Sciences.

high levels of ethylene, prolonged periods in the dark, and temperature fluctuations during shipping can cause leaf drop, petal and bud drop, and wilting by the time the crop reaches the retailer.

Characterization of Quality Decline Symptoms in a Postharvest Environment

The quality of a plant was broken into two categories: inner quality and outer quality by Hendriks (2001) who defined the outer quality as the visible characteristics of a plant. Characterizing the inner quality was deemed more difficult. Postharvest quality has been based on outer quality of plants and how rapidly quality of the plant decreases once it leaves the greenhouse. Noordegraaf (1995) simply described quality as “that which the consumer likes”. Nell and Hoyer (1995) stated that flowering plants should live a minimum of two weeks in an interior environment.

There are many causes of postharvest decline. The quality of a plant postharvest is affected by the conditions it was exposed to during production as well as conditions during transport and storage. Hendriks (2001) highlighted many production factors that can affect plant quality postharvest. These factors include light, temperature, humidity, space, fertilization, and irrigation. Light affects branching, flower color, flower production, and carbohydrate reserves in pot plants (Noordegraaf, 1995). Day and night temperature is important in many species, the difference between the two is known as DIF. In poinsettias (*Euphorbia pulcherrima* Willd.) a negative DIF (day temperature lower than night temperature) increased cyathia drop postharvest (Nell et al., 1995). Miller et al. (1993) found a negative DIF on lilies (*Lilium longifolium* Thunb.) decreased

height but also decreased carbohydrate reserves. High humidity affects nutrient uptake because mass flow into the roots is reduced. *Botrytis* spp. (botrytis) infestations are also promoted by high humidity levels (Hendriks, 2001). Space contributes to other factors mentioned. Small space between plants reduces air flow creating high humidity levels within the leaf canopy. Space also affects the wavelength of light (reduces red light to far red light) that reaches the lower leaves of the plants, this can cause increased internode length. If plants undergo water stress they become more susceptible to insect and disease problems as well as leaf chlorosis and abscission (Dole and Wilkins, 1999).

Different cultivars within a species may have different postharvest longevity. Miller and Heins (1986) found significant differences in cyathia abscission between poinsettia cultivars when they were placed in a postharvest room. Tjosvold et al. (1995) found 'Orange Meilandina' and 'Belle Sunblaze', two cultivars of miniature roses (*Rosa hybrida* L.) showed significantly more leaf chlorosis and abscission after seven and fourteen days in simulated indoor conditions than 'American Independence' and 'Scarlet', two other rose cultivars. Mueller et al. (2001) also found differences between two miniature rose cultivars (Krodana 'Vanilla' and Parade 'Bronze') in ethylene sensitivity. *Kalanchoe blossfeldiana* Poelln. (kalanchoe) cultivars have shelf lives that vary by several weeks. They also differ in ethylene sensitivity (Serek and Reid, 2000). These differences are examples of why difficulties exist in drawing conclusions and generalizing recommendations for a species.

The common physiological disorders seen in potted plants include leaf chlorosis, leaf abscission, bud drop, flower shattering, and stem elongation. Exposure to

unfavorable conditions results in different responses depending upon the plant species. For example, poinsettias display bract discoloration, leaf chlorosis, epinasty (downward bending of leaves due to growth on upper side of the leaf), and an increased susceptibility to botrytis when exposed to unfavorable shipping conditions (Nell et al, 1995).

Shipping Duration and Temperature

Conditions during transport and storage affect postharvest quality of plants. During marketing, plants are packaged to be shipped. Many growers box plants for shipment while other growers transport plants on carts when moving them by truck (Armitage, 1993). Packaged plants are exposed to conditions including low light intensities, temperature fluctuations, elevated ethylene concentrations, and high humidity. Exposure to these conditions can lead to physiological disorders and disease problems. In an overview of shipping Noordegraaf (1995) cited humidity levels above 90% during transport as favorable conditions for botrytis attack.

Poinsettias have a variety of factors that can affect their postharvest quality. They are sensitive to temperature and will display leaf abscission when exposed to low and high [3 °C (38 °F) and 25 °C (78 °F)] temperatures for more than four days and during simulated shipping studies (Nell and Barrett, 1986a). Cyathia abscission was seen during postharvest. Miller and Heins (1986) surmised that reduced light levels contribute to this problem although they noted differences in the amount of abscission

between various cultivars, which ranged between 0% to 69% abscission 70 days after the start of short days.

Nell et al. (1995) studied the effect of transport on potted Asiatic and Oriental lilies. They found plant longevity decreased depending on the length of the transport and the temperature the plants were exposed to during shipping. They simulated shipping at 2°C (35°F), 8°C (45°F), and 13°C (55°F) for 3, 6, and 9 days. The plants showed the greatest decrease in quality when shipped at 13°C (55°F) for 6 days or more.

Nell and Noordegraaf (1991) simulated transport and evaluated several cultivars of miniature roses for three weeks postharvest. Transport was simulated for 3, 6, and 9 days and at 5°C (40°F), 11°C (50°F), and 17°C (60°F). They did not see a significant difference between shipping temperatures at 3 and 6 days of simulated shipping. One and three weeks after shipping there was no significant difference in number of open flowers due to shipping duration. Two weeks after simulated shipping there was an interaction in flower number between temperature and shipping duration. They found the cultivars reacted differently to the shipping and postharvest environment. 'Orange Rosamini' lasted for nine days of shipping at 5 °C while 'Sweet Rosamini', 'Favorite Rosamini' and 'Golden Rosamini' were more sensitive to shipping. They found high postharvest light levels could overcome any detrimental effects of transport. Shoot abortion was noticed in low light levels 2-3 weeks postharvest.

Hoyer (1995) assessed ethylene buildup during transport of potted plants. He monitored two controlled temperature delivery trucks over seventy deliveries of various flowering crops. These collection dates were spread over eighteen months. Samples

were collected from three locations within the trucks every 4-6 hours. Differences in ethylene buildup were found between the two trucks. The average ethylene concentration for one of the trucks was $0.04 \mu\text{L}\cdot\text{L}^{-1}$. High concentrations of ethylene were not measured in the other truck. He concluded there were many factors that could have caused the high ethylene concentration in the delivery truck. The heating system, walls (polyester wall with polyurethane foam insulation), previous plant material cargo (including fruits and vegetables), and rate of air exchange within the truck are all cited as possible reasons for the higher concentration of ethylene.

Ethylene and Ethylene Inhibitors

Ethylene is a plant hormone associated with plant maturation processes. Its presence encourages fruit to ripen, flowers to open, but it is also associated with leaf and flower senescence. Ethylene is synthesized in plant tissues, especially in the reproductive organs. Following pollination, the rate of ethylene biosynthesis increases in a very short amount of time. The ethylene production progresses from the tip of the style and travels basipetally to the base. It has been suggested the hormone acts in inter-organ communication. This pollination induced signaling may promote petal senescence (Woodson and Jones, 2003). For potted plant producers ethylene promoted senescence is of concern since a build up during transport can occur.

Flowering and foliage potted plants display different responses to ethylene. Woltering (1987) studied 26 foliage potted plants and 26 flowering potted plants in order to classify their ethylene sensitivity. He studied the most economically important plants

at that time in the Netherlands. The plants were exposed for 0, 3, 9 or 15 $\mu\text{L}\cdot\text{L}^{-1}$ ethylene in a fumigation chamber in complete darkness and 20 °C for 24 or 72 hours. The ethylene was injected into the chamber and levels were monitored throughout the fumigation. The control plants were held in identical conditions except the ethylene in the environment was removed. He classified the plant sensitivity to ethylene on a dose response curve. There was no uniform response in leaf abscission. Most of the plants (flowering and foliage) abscised old leaves before young leaves but *Capsicum annuum* L. abscised young leaves first. *Dizygotheca elegantissima* (Hort. Veitch) R. Vig. & Guillaum. and *Browallia speciosa* Hook. displayed leaf abscission in new and old leaves without preference. He found flowering potted plants were more responsive to ethylene than foliage pot plants. Flower, flower buds, and whole inflorescence abscission was seen in over half the flowering species tested. Leaf chlorosis and abscission was also seen but in a much fewer number of species. Any plants with fruit exhibited fruit drop in the presence of ethylene. The foliage pot plants displayed leaf chlorosis and abscission in over half the species grown but their response was not as severe as that of the flowering species.

Willumsen and Fjeld (1995) tested the ethylene sensitivity of ten common flowering potted plants at ethylene concentrations of ten to one hundred times less than those tested by Woltering. Their object was to evaluate the effect of exposure to ethylene at concentrations found during shipping and handling on quality and shelf life of flowering potted plants. The plants were exposed to ethylene in a growth chamber for 96 hours in complete darkness at 20 °C. The levels of exogenous ethylene ranged from

0.01 to 1.0 $\mu\text{L}\cdot\text{L}^{-1}$. They found half the plants [*Catharanthus roseus* (L.) G. Don., *Pelargonium ×hortorum* L.H. Bailey, *Fuchsia ×hybrida* Hort. ex Vilm., *Begonia xhiemalis* Fotsch., *Campanula isophylla* Moretti.] were sensitive even at the lowest ethylene level. *Saintpaulina ionantha* H. Wendl. was sensitive at the 0.05 $\mu\text{L}\cdot\text{L}^{-1}$ concentration, *Calceolaria ×herbeohybrida* Voss, kalanchoe, and *Primula acaulis* (L.) J. Hill were sensitive at an ethylene concentration of 0.1 $\mu\text{L}\cdot\text{L}^{-1}$ and *Cyclamen persicum* Mill. was sensitive at a concentration of 1.0 $\mu\text{L}\cdot\text{L}^{-1}$. The responses to ethylene were flower wilting and abscission, bud wilting and abscission, leaf chlorosis and abscission, epinasty, and flower discoloration. The lower ethylene concentrations are levels plants are commonly exposed to during handling after harvest. This response to ethylene indicates a need for growers to use an ethylene inhibitor prior to a crop leaving the greenhouse in order for them to remain at a high quality until they reach the retail environment.

Van Meeteren and van Gelder (1995) found increased ethylene production in *Hibiscus rosa-sinensis* L. (hibiscus) during dark-induced bud shedding. Potted plants with at least three mature buds were placed in growth chambers at 20 °C and 70% to 80% RH and either 0 or 14 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. The dark treated plants had 50% bud abscission after six days in the chamber while the light treated plants had 0% bud abscission. The increase in ethylene production was not seen in the light treatment. Thaxton et al. (1988) found bud abscission of hibiscus ‘Brilliant Red’ could be inhibited by the presence of silver thiosulfate (STS). A STS treatment of 0 or 4 mM was sprayed to run off a week before plants were placed in a plexiglass chamber at 24 °C in complete

darkness and exposed to $1.0 \text{ mL}\cdot\text{L}^{-1}$ of ethylene for two days. After ethylene exposure plants were placed in a simulated interior environment of 24°C and $16.7 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. The control treatment had 87% bud abscission after the ethylene treatment while the STS treated plants had 1% bud abscission.

STS has been used to delay petal abscission, leaf chlorosis and abscission, and delay flowering and flower abscission in cut flowers and pot plants. Tjosvold et al. (1995) studied the effects of STS and benzyladenine (BA) on leaf chlorosis and leaf and flower bud abscission on potted miniature roses. They found $100 \text{ mg}\cdot\text{L}^{-1}$ BA sprayed to run off and applied one day before harvest reduced leaf chlorosis and had little effect on flower development. Application of 1.0 mM of STS one day prior to harvest increased the number of flowers that matured postharvest but had little effect on leaf chlorosis. A mixture of BA and STS applied one day before harvest showed the best results on the pot roses.

In cut chrysanthemum (*Dendranthema × grandiflorum* Kitam.) crops, stems placed in a GA_3 at 1.0 to $5.0 \mu\text{L}\cdot\text{L}^{-1}$ before shipment had reduced leaf chlorosis but flowers on treated stems were deformed after treatment. Treatments were applied for 4 and 24 hours and then stems were placed in simulated shipping for five days. Postharvest the stems were held in a room at $20/18^\circ\text{C}$ day/ night temperatures and 80 % RH. They found cytokinins applied as a postharvest foliage spray or foliage immersion delayed leaf chlorosis while STS at $25 \text{ mL}\cdot\text{L}^{-1}$ applied as a pre-shipment vase solution had no effect on leaf chlorosis (D'hont et al., 1991). Kelly and Starman found the

presence of 2mM STS in the vase solution caused stems of *Physostegia purpurea* Blake to last twice as long as those held in deionized water (1990)

In 1991, auction houses in Holland mandated STS treatment on certain ethylene-sensitive cut flower crops before arrival at auction. While STS is effective in delaying ethylene processes its use has environmental effects. The silver in STS is a heavy metal. These concerns have caused researchers to study other options available to replace STS and prevent ethylene damage to potted and cut flower crops postharvest (van Doorn and Woltering, 1991).

An alternative to STS for ethylene inhibition is 1-methylcyclopropene (1-MCP). This plant growth regulator has applications in food and floriculture crops. From a research standpoint, 1-MCP is an aid in determining the functions of ethylene as a plant hormone. The mechanism of action for 1-MCP is not fully understood. It is thought to bind to ethylene receptors, which prohibits ethylene from binding to these receptors. 1-methylcyclopropene has a greater affinity to the receptors than ethylene and it is active at lower concentrations than ethylene. It has been speculated that 1-MCP binds to a metal in the ethylene receptors where it remains bound for several days. Since 1-MCP is applied as a gas it is transient and not stored within the plant to bind to receptors formed after application. As new receptors form, plants once again respond to ethylene. Other cyclopropenes also act as ethylene inhibitors but lower concentrations of 1-MCP are needed than that needed by related chemicals (Sisler and Serek, 1997). The transient nature of 1-MCP gas is different from STS complex which moves up the xylem and binds to the ethylene receptor (Veen, 1983).

Muller et al. (2000) found a pretreatment of 1-MCP prolonged the shelf life of miniature potted rose cultivars when held in a simulated interior environment postharvest. The plants were treated with 1-MCP within a sealed glass container for six hours. The 1-MCP was released when 0.2 g of a commercial formulation was mixed with 10 mL of water. In Oriental hybrid lilies (*Lilium* × ‘Mona Lisa’ and ‘Stargazer’), ethylene affects flower and bud longevity as well as leaf chlorosis and senescence. Plants were enclosed in a glass chamber and treated for 18 hours with 500 $\mu\text{L}\cdot\text{L}^{-1}$ 1-MCP gas. Plants were then exposed to 0, 2 or 5 $\mu\text{L}\cdot\text{L}^{-1}$ ethylene for three days. Flower senescence and abscission was significantly delayed by 1-MCP while buds still opened normally. In plants not exposed to ethylene, leaf chlorosis was not affected by the application of 1-MCP. In plants exposed to ethylene, it was found 1-MCP alone or a combination of 1-MCP and a mixture of GA₄₊₇ plus BA (Promalin) applications inhibited ethylene induced leaf senescence (Çelikel et al. 2002). Sankhala et al. (2001) found cut racemes of *Lupinus havardii* Wats. gassed with 1-MCP for 12 to 16 hours had reduced flower abscission and senescence and additional flowers were induced. The extension of vase life opens up retail possibilities for this species.

Serek and Sisler (2001) investigated the efficacy of 1-MCP in prolonging the shelf life of two ethylene sensitive pot plants: *Campanula carpatica* Jacq. (bellflower) and *Schlumbergera truncata* (Haw.) Moran (Thanksgiving cactus). They also compared the shelf life of plants treated with STS to those treated with 1-MCP. The shelf life was extended in all treated plants when compared to an untreated control in an environment containing 0.5 $\mu\text{L}\cdot\text{L}^{-1}$ of ethylene. The shelf life of STS treated plants was about a day

longer than 1-MCP treated plants. In an interior environment without ethylene, 1-MCP did not lengthen shelf life more than the control. However, STS did add at least one day to the shelf life of both species.

Kalanchoe is another ethylene sensitive potted plant. Under normal production and retail circumstances they have a shelf life of between seven and ten weeks. Shelf life is reduced when flowers inroll in response to exposure to low ($0.5 \mu\text{L}\cdot\text{L}^{-1}$) concentrations of ethylene. Exposure to $1.0 \mu\text{L}\cdot\text{L}^{-1}$ of ethylene for 24 h caused flowers to inroll but they recovered within three days, treatments exposed for 32 h or more did not recover. The threshold is low enough that grocery stores – which often sell kalanchoë in their floral departments, surpass the ethylene threshold in their ambient atmosphere. Kalanchoe cultivars had different responses to exposure to $1.0 \mu\text{L}\cdot\text{L}^{-1}$ ethylene; ‘Debbie’ did not inroll after 24 hours exposure to $10 \mu\text{L}\cdot\text{L}^{-1}$ ethylene while ‘Alexandra’ inrolled when exposed to $0.1 \mu\text{L}\cdot\text{L}^{-1}$ ethylene. Treatment with 1-MCP for six hours before placement into the simulated interior environment did not affect flower longevity (Serek and Reid, 2000).

Serek et al. (1994) did find a significant increase in shelf life of kalanchoë, miniature pot roses, and *Begonia ×elatioir hybrida* Fotsch. treated with 1-MCP over untreated plants when held in an environment containing $1 \mu\text{L}\cdot\text{L}^{-1}$ of ethylene. In this experiment there was no difference in shelf life between plants treated with 1-MCP (gassed with 6 to $20 \mu\text{L}\cdot\text{L}^{-1}$ 1-MCP for 6 hours in sealed glass container at $15 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, 20°C) and those treated with STS (sprayed with 0.5 mM STS solution to runoff). Cameron and Reid (2001) found pretreatment with $1.0 \mu\text{L}\cdot\text{L}^{-1}$ 1-MCP for two hours

postponed petal abscission in *Pelargonium peltatum* L. (ivy geranium). They tested flowers at all stages of development from not fully reflexed petals and no visible stigma to reflex petals with fading color and abscised pollen sacs. They found the treated flowers resisted abscising when exposed to $1.5 \mu\text{L}\cdot\text{L}^{-1}$ ethylene for three hours. This resistance decreased (i.e. flower abscission increased) as time after treatment increased. They also found 1-MCP was effective in inducing ethylene resistance on all flowers until the petals were reflexing and the color was faded.

Leaf chlorosis is a concern for vegetative cuttings which do not have many leaves per cutting to begin with. Vegetative cuttings of chrysanthemum, *Pelargonium zonale* L. (zonal geranium) and hibiscus were studied by Serek et al. (1998) in simulated shipping conditions. Freshly collected unrooted cuttings were pretreated with $200 \mu\text{L}\cdot\text{L}^{-1}$ 1-MCP in a glass chamber for six hours, 2 mM STS vase solution for two hours or not treated at all. They were stored in a dark growth chamber at 20 °C for three days following treatment. Chlorophyll content was measured by extraction with 80% ethanol for ten minutes, absorption was measured using a spectrophotometer at 647, 664, and 700 nm. The chlorophyll content in leaves treated with 1-MCP or STS was significantly higher than the content in the control plants for the zonal geraniums. Visible differences were seen in hibiscus but chlorophyll content was not significant. There were no differences visibly or chemically in the chrysanthemum cuttings.

After storage the cuttings were rooted in an aerated nutrient solution in a greenhouse at 20 °C, 75% RH, $120 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ for 4 to 6 weeks species dependent. After rooting the treated chrysanthemum and hibiscus cuttings had significantly fewer

roots than the controls did. Plants treated with 1-MCP produced significantly more roots than those treated with STS. In zonal geranium 1-MCP treated plants produced significantly more roots than STS treated plants but there was no difference between treated plants and the control plants.

In fruit and vegetable crops, 1-MCP is used as an aid to prolong quality during storage. It has been found to be beneficial on some food crops like *Fragaria ×anaassa* Duchesne. (strawberry) whether or not exogenous ethylene is present; in other food crops like *Brassica rapa* L. (pak choi) and *Brassica oleracea* L. (broccoli) it is only beneficial in the presence of exogenous ethylene. It was found to reduce ethylene production in strawberry, *Prunus salicina* Lindl. (plum), *Prunus armeniaca* L. (apricot), and *Malus domestica* Borkh. (apple). In *Ananas comosus* (L.) Merril. (pineapple), *Coriandrum sativum* L. (coriander) and *Citrus paradisi* McFady (grapefruit) 1-MCP increased ethylene production. Even though ethylene production by grapefruit increased with 1-MCP treatment the fruit stayed green. In tomato (*Lycopersicon esculentum* L.), strawberry, plum, apricot, carrots (*Daucus carota* L.), banana (*Musa paradisiaca* L.), and apple, 1-MCP was found to reduce respiration rates (Blankenship and Dole, 2003).

Effects of Production Nutrition – Nitrogen

Postharvest studies involving nutrition have been conducted on several major floriculture crops such as chrysanthemum and poinsettia. In his review, Druege (2001) reported high levels of nitrogen applied during the last weeks of production promoted leaf and flower senescence postharvest. High nitrogen influenced carbohydrate

allocation and storage. Low carbohydrate reserves reduced survival in low light interior conditions. Studies involving three cultivars of chrysanthemum ('Copper Hostess', 'Iridon', and 'Tip') found a significant interaction in longevity postharvest between cultivar and nitrogen concentration (1.2, 2.6, or 5.2 kg·m⁻³). 'Tip' decreased in longevity with increased nitrogen concentration while longevity of the other two cultivars was not affected by nitrogen concentration. The plants were fertilized until flowering with 300 ml fertilizer at each irrigation event. The postharvest environment was a simulated interior room set at 20±1 °C, 12 µmol·m⁻²·s⁻¹ for 12 hrs/day, and 50% RH. They also found a significant interaction between the concentration of nitrogen applied and the growing media used (Vergro Klay Mix, Metro Mix 350, and a peat:perlite:sand mix were tested). Longevity was decreased with increase nitrogen concentration in Metro Mix while concentration did not affect longevity in Vergro Klay mix or the peat-perlite-sand media (Roude et al., 1991). Nell et al. (1989) showed that ceasing fertilization on chrysanthemums three weeks before harvest increased postharvest longevity by up to seven days. In addition, they found decreasing light levels from 500 to 300 or 100 µmol·s⁻¹·m⁻² about three weeks before flowering decreased chrysanthemum longevity by 5-16 days. Ter Hell and Hendriks (1995) found that high levels of nitrogen increased bud drop and leaf drop in pot roses and *Impatiens hawkeri* Bull. (New Guinea Impatiens). They tested nitrogen levels of 50, 100 and 150 mg·L⁻¹ on the New Guinea impatiens and 100 and 200 mg·L⁻¹ on pot roses. Plants were fertilized at each irrigation event. A 15% increase in leaf and bud drop was noted for impatiens fertilized with 150 mg·L⁻¹ of nitrogen, over those fertilized with 100 mg·L⁻¹ until harvest. Roses showed a

30% increase in leaf and bud drop when fertilized with 200 mg·L⁻¹ over 100 mg·L⁻¹ of nitrogen until one month before harvest. They also compared the effects of fertilizing with ammonium [(NH₄)₂SO₄] to fertilizing with a nitrate [Ca(NO₃)₂] on the two species. They compared 50 and 150 mg·L⁻¹ nitrogen on New Guinea impatiens and 100 and 200 mg·L⁻¹ nitrogen on pot roses. They found ammonium caused more damage than nitrates when the plants were fertilized with the same nitrogen concentration.

Nell and Barrett (1986b) found incidence of bract necrosis in poinsettia 'Gutbier V-14 Glory' decreased if the amount of fertilizer was 100 mg·L⁻¹ compared to necrosis on plants fertilized with 200 and 400 mg·L⁻¹ while growing and ceased after the bracts began to color. They also found plants were three and a half times more likely to have necrosis if they were well-watered and fertilized than if fertilization was terminated and plants were not watered until visible wilt after bract color was seen. Total inflorescence diameter and bract size was reduced on the water-stressed plants.

Macz et al. (2001) found a combination of at least 100 mg·L⁻¹ of nitrogen and 10 mg·L⁻¹ of sulfur produced chrysanthemum plants with acceptable plant height, inflorescence size, anthesis and longevity postharvest. The leaf area was smaller than plant receiving a higher rate of nitrogen. Sulfur was a necessary nutrient to add with nitrogen, without sulfur the plants were stunted with chlorotic leaves and delayed inflorescence. At 5.0 mg·L⁻¹ of sulfur plants were not an acceptable quality but they lasted as long postharvest as higher sulfur rates.

Braswell et al. (1982) found *Schefflera arboricola* Hayata ex. Kanehira and *Brassaia actinophylla* Endl. performed better after three months in an interior

environment (20 °C, 50% RH, continuous $16 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, watered as needed) if they received 200 $\text{mg}\cdot\text{L}^{-1}$ of nitrogen than if they received 400 $\text{mg}\cdot\text{L}^{-1}$ during production. Plants were not fertilized postharvest. *Schefflera arboricola* had a lower growth index, stem diameter, internode length, fresh weight, and plant grade with the higher nitrogen rate after three months in the interior environment. In *B. actinophyll*, plants from the high fertilizer treatment had significant small stem diameter, more leaf drop, lower chlorophyll content, and lower plant grade than those from the low fertilizer treatment. Higher light levels during production did not improve chlorophyll, internode length, stem diameter, or reduce leaf drop for *S. arboricola*. In *B. actinophylla* light levels during production did affect postharvest performance. Those receiving higher light levels showed differences in all factors measured except leaf drop which had no significant differences.

Effect of Thidiazuron (TDZ) on Plant Quality

Thidiazuron is a diphenylurea derivative. It has cytokinin like activities. In soybean (*Glycine max* (L.) Merrill) callus it stimulated the synthesis and accumulation of purine cytokinin. Metabolism of cytokinin in tobacco plantlets was also (Thomas and Katterman, 1986). These properties are why TDZ is used in tissue culture to stimulate callus growth. Capelle et al. (1983) found TDZ to be highly active in callus tissue of *Phaseolus lunatus* L.

In agriculture, TDZ is used as a defoliant particularly in cotton. It is sprayed on a field to defoliate the plants before the boll harvest. Snipes and Cathey (1992) found that

a tank mix of TDZ and another defoliant (they tested ethephon, tribufos, and dimethinpin) worked well to negate the effect of environmental conditions on the efficacy of the chemicals in promoting leaf abscission.

The use of TDZ to prevent leaf chlorosis was investigated in cut *Alstromeria pelegria* L. (alstromeria) by Ferrante et al. (2002). They researched the amount of time between harvest and leaf chlorosis on cultivars of alstromeria. This experiment was conducted by placing cut stems in a TDZ solution for 24 hours. They found the TDZ at a concentration of 10 μmol or larger postponed leaf chlorosis for more than two months. The control plants had chlorotic leaves between six and ten days postharvest.

Thidiazuron has also been tested on cut tulips (*Tulipa gesneriana* L.) and cut chrysanthemum (Ferrante et al., 2003). These stems were pulsed in a TDZ solution of 10, 50, or 100 μmol for 24 h and then were stored in distilled water holding solution postharvest. In tulips stem elongation was reduced and leaf chlorosis was delayed by at least eleven days past the control plants. The chrysanthemum cultivars showed a cultivar dependent response. One cultivar showed a difference between the treated and control stems in leaf chlorosis. The other cultivar displayed stem wilting before leaf chlorosis appeared on either treatments. In both species the chlorophyll content in the treated groups increased after harvest.

In cut *Eucalyptus parvifolia* Cambage. stems placed in solutions containing 10, 50, or 100 μmol of TDZ for 24 hours, vase life was significantly extended when compared to stems placed in benzyladenine although there was no significance between

the TDZ treatments and the control. Chlorophyll degradation was inhibited by TDZ at all rates (Ferrante, et al., 2002).

Effects of TDZ on potted plants have not been studied in much detail. King et al. (2001) found TDZ effective in reducing leaf chlorosis and senescence in poinsettia during four weeks of simulated interior environment. The control plants lost up to 30% of their leaves during this same time period.

CHAPTER II

EFFECT OF SHIPPING DURATION AND NITROGEN TONING ON 21 VEGETATIVE ANNUAL CULTIVARS POSTHARVEST QUALITY AND LONGEVITY

Introduction

Vegetative annuals are plants propagated vegetatively and sold to the consumer as an annual, whether as a bedding plant or for container use. They are becoming increasingly popular in the floriculture industry because they offer something new and different to consumers. Quality of vegetative annuals is relatively easy to maintain during production because propagative material is virus indexed and stock plants are grown uniformly (Henne, 2002).

Most research into postharvest responses of flowering potted plants has focused on *Dendranthemum × grandiflorum* Kittam. (chrysanthemum), *Rosa hybrida* L. (pot roses), and *Euphorbia pulcherrima* Willd. (poinsettias). For newer vegetative annual crops postharvest responses and factors that influence them, have not been studied.

High temperatures during shipping and long shipping durations have reduced postharvest longevity of potted plants. Nell and Barrett (1986a) simulated shipping on ‘Gutbier V-10 Amy’ poinsettia at 4, 16, and 24 °C for 1, 4, or 7 days. After shipping the plants were placed in a simulated interior at 21 °C, 50% RH, and 20 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ for 30 days. After the 30 days they found the plants shipped for seven days at the two higher temperatures displayed the highest amount of leaf abscission (36 leaves compared to 12

and 0 as the length of simulated shipping decreased). Cyathia abscission was greater on treatments shipped for four or seven days at 16 or 24 °C. Those shipped for one day at any temperature had a maximum of one cyathia abscised per plant and no leaves abscised. Cushman et al. (1998) found an interaction between shipping temperature and storage (simulated shipping) duration on pot roses. Floral longevity decreased when plants were shipped at 16 °C for more than four days. When the shipping temperature was increased to 28°C floral longevity was found to decrease when shipped for more than two days. Leaf abscission was found to increase at these same points.

Ethylene levels and duration of exposure affect postharvest quality. Woltering (1987) tested 26 flowering plant species and found flower, flower bud, and leaf abscission common symptoms after exposure to 0, 3, 9, or 15 $\mu\text{L}\cdot\text{L}^{-1}$ ethylene for 24 or 72 h at 20 °C and 0 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. Serek and Reid (2000) measured the effect of ethylene on flowers of *Kalanchoe blossfeldiana* Poelln. ‘Alexandra’ treated with 1.0 $\mu\text{L}\cdot\text{L}^{-1}$ ethylene for 2, 4, 8, 24 and 32 h. They found those treated for >8 hours displayed inrolling of the flowers and a decrease in flower diameter. The flowers exposed for 24 h recovered over the days following treatment while the flowers treated for 32 h did not recover but wilted and senesced.

High relative humidity during shipping has been found to cause wet conditions that could promote disease. When refrigerated van containers holding *Chrysalidocarpus lutescens* H. Wendl. (Areca palm) were shipped from Florida to Europe (14 to 16 days from packing to unpacking) relative humidity was found to affect plant quality after shipping. The containers with a relative humidity between 90 and 100% during shipping

had free water on the leaves and the paper sleeves were wet. The container with a relative humidity set at 80% (ranged between 75% and 90%) did not have moisture on the plants but the sleeves were damp. Although plant quality was not affected for this species, it was noted that black and decaying leaves are common results of free water on the leaves of ornamentals with lush leaves (Risse et al., 1989).

Conditions such as temperature, nutrition, irrigation practices and plant spacing during production can affect crop quality postharvest. The difference between day and night temperatures (DIF) can affect bract necrosis and cyathia abscission of poinsettia. Poinsettias grown at a negative DIF from bract coloring to a marketable stage showed increased bract necrosis when held in simulated interior conditions (20 °C, 40% to 50% RH, $13.5 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ for 12 h/day) for four weeks compared to those grown at a positive or no DIF. Cyathia abscission during the first 2 weeks postharvest was greater on plants grown in negative DIF throughout production compared to those exposed to positive or no DIF (Moe et al., 1992).

Irrigation frequency during production affects postharvest quality of pot roses. Pot roses were grown under four watering regimes after a second pinch until flowering (38 days). The control (amount watered daily equal to evapotranspiration) had more buds postharvest but the roses grown in water deficit or cyclical water stress conditions had more buds open to flowers and had less flower and bud damage than the control plants did (Williams et al., 2000).

Reducing nitrogen fertilization during production increased postharvest quality or longevity of poinsettia, chrysanthemum, and *Campanula carpatica* Jacq. potted

plants. The application of a reversible stress to increase its tolerance of mechanical or environmental adversities is defined as toning by Nelson (1998). Nitrogen toning can be conducted by completely discontinuing fertilization the last two weeks of production or by reducing fertilizer rate to half the concentration or frequency. Nell et al. (1989) found postharvest shelf life of chrysanthemums was increased by up to seven days if fertilization was ceased three weeks before harvest (8 weeks into production). Nell and Barrett (1986b) found less bract necrosis occurred on poinsettias when fertilized from planting with 100 mg·L⁻¹ N until bract color than treatments fertilized with 200 and 400 mg·L⁻¹ until bract color (ten weeks of production) or any fertilizer concentration until harvest (15 weeks of production). Bract necrosis also decreased in well watered poinsettias if fertilized with 300 mg·L⁻¹ N until bract color and then terminated. Serek (1990) found high fertilization levels (300 mg·L⁻¹ N) before simulated shipping induced earlier flowering in *Campanula carpatica* than low and no fertilization. The plants treated with high fertilizer flowered earlier but the flowers senesced earlier than the other treatments. Low and no fertilizer treatments flowered longer during the postharvest period which extended their shelf life.

Materials and Methods

COMMON PROCEDURES

COOL SEASON VEGETATIVE ANNUALS. Twenty milliliter rooted liners (105 rooted liners/tray) from Flower Fields (Paul Ecke Ranch, Encinitas, CA) were received on 7 Jan. 2003 and planted on 10 and 13 Jan. Twenty seven milliliter rooted liners (34

rooted liners/strip, 3 strips/tray) from Simply Beautiful (Ball FloraPlant, Chicago, IL) were received on 14 Jan and planted on 15 and 16 Jan (Table 1). Due to the loss of a shipment of rooted liners from a third supplier, extra species and cultivars from Paul Ecke Ranch and Ball FloraPlant were planted on 24 and 25 Jan. All were planted in soil-less media (Pro Mix BX, Premier Brands, Quakertown, PA) in 11.4 cm (415 mL) geranium pots (Dillon Products, Middlefield, OH).

Plants were watered by hand and fertilized at each irrigation. From planting to 28 Jan., 15N-5.4P-14.1K (Peter's Professional, Scotts-Sierra Horticultural Products Company, Marysville, OH) water-soluble fertilizer was used at $200 \text{ mg}\cdot\text{L}^{-1}$. From 29 Jan. to 11 Feb., fertilizer rate was increased to $300 \text{ mg}\cdot\text{L}^{-1}$. From 12 Feb. until harvest, 20N-3.4P-16.6K (Peter's Professional, Scotts-Sierra Horticultural Products Company, Marysville, OH) fertilizer was applied at $300 \text{ mg}\cdot\text{L}^{-1}$. On 31 Jan. and at four week intervals from this date, Soluble Trace Element Mixture (STEM, Peter's Professional, Scotts-Sierra Horticultural Products Company, Marysville, OH) drench was applied to the plants at $30 \text{ mg}\cdot\text{L}^{-1}$. On 11 Mar., calibrachoa and petunia cultivars received a 20% iron sulfate drench to lower substrate pH and prevent iron deficiency symptoms i.e. chlorosis of new foliage. Calibrachoa cultivars received another 20% iron sulfate drench on 28 Mar.

Plants were grown in a glass greenhouse at $18^{\circ}/16^{\circ}\text{C}$ day/night temperature set points until 24 Jan. when the night temperature was lowered to 13°C . Greenhouse light levels were measured using an Integrated Spectrum Datalogger (Apogee Instruments

Table 1. Vegetative annual genus, species, authority, cultivar, propagator and common name.

Genus	Species	Authority	Cultivar	Propagator ¹	Common name
<i>Angelonia</i>	<i>angustifolia</i>	Benth.	Carita Lavender	FF	angelonia
<i>Argyranthemum</i>	<i>frutescens</i>	(L.) Sch. Bip.	Comet White	FF	argyranthemum, marguerite daisy
<i>Argyranthemum</i>	<i>frutescens</i>	(L.) Sch. Bip.	Sunlight	FF	argyranthemum, marguerite daisy
<i>Bracteantha</i>	<i>bracteata</i>	(Vent.) Anderb. & Haegi	Florabella White	FF	bracteantha, straw flower
<i>Bracteantha</i>	<i>bracteata</i>	(Vent.) Anderb. & Haegi	Florabella Gold	FF	bracteantha, straw flower
<i>Bracteantha</i>	<i>bracteata</i>	(Vent.) Anderb. & Haegi	Dreamtime Copper	SB	bracteantha, straw flower
<i>Bracteantha</i>	<i>bracteata</i>	(Vent.) Anderb. & Haegi	Dreamtime Cream	SB	bracteantha, straw flower
<i>Bracteantha</i>	<i>bracteata</i>	(Vent.) Anderb. & Haegi	Sundaze Bronze	PW	bracteantha, straw flower
<i>Bracteantha</i>	<i>bracteata</i>	(Vent.) Anderb. & Haegi	Sundaze Golden Yellow	PW	bracteantha, straw flower
<i>Calibrachoa</i>	hybrid	Lave Lex	Liricashowers Deep Blue Improved	FF	calibrachoa
<i>Calibrachoa</i>	hybrid	Lave Lex	Starlette Trailing Purple	SB	calibrachoa
<i>Calibrachoa</i>	hybrid	Lave Lex	Superbells Trailing Blue	PW	calibrachoa
<i>Diascia</i>	× <i>hybrida</i>		Sun Chimes Coral	FF	diascia

Table 1 continued.

Genus	Species	Authority	Cultivar	Propagator ¹	Common name
<i>Lantana</i>	<i>camara</i>	L.	Lucky Lemon Cream	SB	lantana
<i>Lantana</i>	<i>camara</i>	L.	Lucky Peach Sunrise	SB	lantana
<i>Nemesia</i>	× <i>hybrida</i>		Aromatica White	SB	nemesia
<i>Nemesia</i>	× <i>hybrida</i>		Vanilla Sachet	FF	nemesia
<i>Petunia</i>	× <i>hybrida</i>	Hort.	Cascadias Pink	FF	petunia
<i>Petunia</i>	× <i>hybrida</i>	Hort.	Suncatcher Pink	SB	petunia
<i>Sutera</i>	<i>hybrida</i>		Bridal Showers	FF	sutera, bacopa
<i>Sutera</i>	<i>cordata</i>		Candy Floss Blue	FF	sutera, bacopa

¹FF = Flower Fields, PW = Proven Winners, SB = Simply Beautiful

Inc., Logan, UT). Actual greenhouse temperatures were measured using HOBO H8 loggers (Onset Computer Corp., Bourne, MA) (Appendix A).

All plants received a broad spectrum fungicide drench { {Etridiazole (5-Ethoxy-3-trichloromethyl-1,2,4-thiadiazole) and Thiophanate {thiophanate- methyl[Dimethyl(1,2-phenylene) bis (iminocarbonothioyl)] bis (carbamate)}}; Banrot 40%WP, Scotts-Sierra Crop Protection Company, Marysville, OH} } at 59.8 mg·L⁻¹ on 24 Jan. to prevent root rot diseases. Diascia and nemesia cultivars were treated for stem rots with Iprodione [(3-(3,5-dichlorophenyl)-N-(1-methylethyl)-2,4-dioxo-1-imidiazolidinecarboxamide); Chipco 26019 50% WP; Chipco; Aventis Environmental Science USA LP, Montvale, NJ] at 2.38 g·L⁻¹ on 10 Feb. Imidacloprid {1-[(6-Chloro-3-pyridinyl)methyl]-N-nitro-2-imidazolidinimine; Marathon 1% Granular; Olympic Horticultural Products, Mainland,

PA} was applied to calibrachoa and petunia cultivars on 21 Feb. at 1.4 g/pot for systemic insect control.

Petunia cultivars had been sporadically pinched by the grower, any petunia plants not pinched previously were pinched on 31 Jan. Sutura ‘Bridal Showers’ and ‘Candy Floss Blue’ were pinched on 7 Feb. A paclobutrazol $\{ \{ \text{B}-[(4\text{-chlorophenyl)methyl}]\text{-}\alpha\text{-(1,1-dimethyl)-1}H\text{-1,2,4-triazole-1-ethanol} \}$; Bonzi; Uniroyal Chemical, Middlebury, Conn.} (40 mg·L⁻¹) and daminozide [butanedioic acid mono (2,2-dimethylhydrazide); B-Nine; Uniroyal Chemical] (2500 mg·L⁻¹) tank mix was applied as a foliar spray to runoff to selected cultivars for height control. They included *B. bracteata* ‘Florabelle White’ treated on 24 Jan., *B. bracteata* ‘Florabelle Gold’ and *A. frutescens* ‘Sunlight’ on 31 Jan., and *A. frutescens* ‘Comet White’ on 5 Feb.

WARM SEASON VEGETATIVE ANNUALS. Twenty seven milliliter rooted liners from Simply Beautiful, and 20 mL rooted liners from Flower Fields and 20 mL rooted liners (84 rooted liners/tray) from Proven Winners (EuroAmerican Propagators, Bonsall, CA) were received on 26 and 27 Feb. and planted on 12 Mar. All were planted in soil-less media (Sunshine Mix #1, SunGro Horticulture Inc, Pine Bluff, AK). Pot size depended on growth habit of the cultivar and included 11.4 cm geranium (415 mL), standard (440 mL), 12.7 cm azalea pots (535 mL) (Dillon Products, Middlefield, OH) or 11.4 cm azalea pots (430 mL) (ITML Horticultural Products Inc., Brantford, Ontario). The plants were grown at 18°/13 °C day/night temperature set points until 24 March when the temperature set points were increased to 24°/18 °C day/night. A 50% interior shade cloth was applied on 2 Apr. for the remainder of the experiment.

Plants were watered by hand and fertilized at each irrigation with 20N-3.4P-16.6K at $300 \text{ mg}\cdot\text{L}^{-1}$. Soluble Trace Element Mixture was applied every four weeks. All plants received a Banrot drench ($59.8 \text{ mg}\cdot\text{L}^{-1}$) on 24 Mar. On 28 Mar., calibrachoa cultivars received a 20% iron sulfate drench. Marathon (1.4 g/pot) was applied to all plants on 28 March for systemic insect control.

EXPERIMENT 1 – EFFECT OF SIMULATED SHIPPING DURATION ON POST-HARVEST PERFORMANCE. There were three shipping treatments. Plants of 21 cultivars were subjected to simulated shipping for 0 (control), 1, or 2 days before postharvest evaluation. Each treatment consisted of six plants per cultivar. Plants were placed in simulated shipping, i.e. growth chamber at $26.7 \pm 0.3 \text{ }^{\circ}\text{C}$, $0 \text{ }\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, and 50% RH.

EXPERIMENT 2 – EFFECT OF NITROGEN TONING ON POSTHARVEST PERFORMANCE. Two weeks prior to and until harvest, plants were subjected to nitrogen toning i.e. one of three rates of fertilization with 20N-3.4P-16.6K. Nitrogen toning treatments were continuation of fertilization at $300 \text{ mg}\cdot\text{L}^{-1}$ [100% production fertilization rate (PFR)], reduction in fertilization to $150 \text{ mg}\cdot\text{L}^{-1}$ (50% PFR) and termination of fertilization to $0 \text{ mg}\cdot\text{L}^{-1}$ (0% PFR). There were six replications of each cultivar per treatment. Plants were harvested when they were judged marketable. After harvest plants were moved directly to the growth room (i.e. no simulated shipping) for postharvest evaluation.

Data taken at harvest included plant height, plant width index and number of flowers. Plant height was measured from the base of the pot to the highest point on the plant. Plant width index was the mean of two plant width measurements taken perpendicularly across the plant canopy.

POSTHARVEST EVALUATION. Plants were placed in a growth room at 21.1 ± 1.3 °C with an average light intensity of $6 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (measured with a hand-held quantum meter, Spectrum Technologies, Inc., Apogee Manufacturing Inc., Logan, UT). Flower number was counted and a plant quality rating (5 to 0 scale, 5 being highest quality, Table 2) were given to each plant as they were moved from the growth chamber (expt. 1) to the growth room. Plants remained in the growth room for three weeks. Flower number and quality rating were recorded weekly during postharvest evaluation. A plant was no longer considered marketable if the quality rating was lower than rating 3.0.

Table 2. Postharvest quality rating.

Rating	Plant response
5	Plant is healthy – no visible decline symptoms
4	<50% flower abscission and/or visible change in flower color and/or <10% chlorotic lower leaves
3	100% flower abscission and/or <50% chlorotic lower leaves and/or <10% senesced lower leaves
2	>50% senesced lower leaves and 100% flower abscission and/or <10% dead stems
1	>10% dead stems, 100% flowers abscised and/or 100% lower leaves senesced
0	Total plant senescence

Harvest data was analyzed using ANOVA and Least Squared Difference (LSD) test by the SAS program (SAS 8.01; SAS Institute, Cary, NC). Postharvest flower data was analyzed using repeated measure analysis conducted as a split plot design using the Proc Mixed procedure in SAS with LSD for mean separation. Postharvest quality ratings were analyzed as repeated measure categorical data with the Proc Genmod procedure in SAS with Chi-squared for mean separation.

Results

The postharvest decline symptoms observed during this postharvest evaluation are in Table 3. This table is observational data and is included for quick reference. The at harvest measurements (plant height, width index, and number of open flowers) in experiment one showed no differences between the variables measured and will not be discussed further.

Angelonia angustifolia

Only one cultivar of angelonia was grown in our experiments. Angelonia ‘Caritas Lavender’ is an upright plant with medium green linear leaves and purple flowers. Plants averaged 52.67 cm tall, 40.00 cm wide at the top and had 11.6 individual flowers when harvested. Lower leaf chlorosis was noted on angelonia after one week postharvest. Internode elongation occurred at the acropetal end of the stems on new growth in weeks two and three of the evaluation (Table 3).

Table 3. Visual observations of postharvest decline symptoms on vegetative and reproductive tissues of vegetative annuals.

Species	Cultivar	Lower leaf	Bud	Internode	Flower color	Flower size	Stem	Flower
		chlorosis	abortion	elongation	fading	decrease	dieback	senescence
<i>Angelonia angustifolia</i>	Caritas Lavender	X		X				
<i>Argyranthemum frutescens</i>	Comet White	X						
<i>Argyranthemum frutescens</i>	Sunlight	X	X					
<i>Bracteantha bracteata</i>	Dreamtime Copper	X	X					
<i>Bracteantha bracteata</i>	Dreamtime Cream	X	X					
<i>Bracteantha bracteata</i>	Florabella Gold	X	X	X				X
<i>Bracteantha bracteata</i>	Florabella White	X	X	X				X
<i>Bracteantha bracteata</i>	Sundaze Bronze	X	X					
<i>Bracteantha bracteata</i>	Sundaze Golden Yellow	X	X					
<i>Calibrachoa</i> hybrid	Liricashowers Deep Blue Imp.	X		X	X	X	X	
<i>Calibrachoa</i> hybrid	Starlette Trailing Purple	X		X				X
<i>Calibrachoa</i> hybrid	Superbells Trailing Blue	X		X	X	X		
<i>Diascia</i> × <i>hybrida</i>	Sunchimes Coral	X			X		X	
<i>Lantana camara</i>	Lucky Peach Sunrise and							X
<i>Lantana camara</i>	Lucky Lemon Cream							X

Table 3 continued.

Species	Cultivar	Lower leaf	Bud	Internode	Flower color	Flower size	Stem	Flower
		chlorosis	abortion	elongation	fading	decrease	dieback	senescence
<i>Nemesia</i> × <i>hybrida</i>	Vanilla Sachet	X		X				
<i>Nemesia</i> × <i>hybrida</i>	Aromatica White	X		X				
<i>Petunia</i> × <i>hybrida</i>	Cascadias Pink	X						
<i>Petunia</i> × <i>hybrida</i>	Suncatcher Pink	X			X			X
<i>Sutera hybrida</i>	Bridal Showers			X		X		X
<i>Sutera cordata</i>	Candy Floss Blue						X	X

Table 4. F-test of the effect of nitrogen toning on plant height, width index and flower number at harvest.

Plant Species	Cultivar	Plant height	Width index	Flower number
<i>Angelonia angustifolia</i>	Caritas Lavender	NS	NS	NS
<i>Argyranthemum frutescens</i>	Comet White	**	*	NS
<i>Argyranthemum frutescens</i>	Sunlight	NS	NS	NS
<i>Bracteantha bracteata</i>	Dreamtime Copper	NS	***	NS
<i>Bracteantha bracteata</i>	Dreamtime Cream	NS	**	NS
<i>Bracteantha bracteata</i>	Florabella Gold	NS	***	NS
<i>Bracteantha bracteata</i>	Florabella White	NS	*	NS
<i>Bracteantha bracteata</i>	Sundaze Bronze	*	NS	NS
<i>Bracteantha bracteata</i>	Sundaze Golden Yellow	NS	NS	NS
<i>Calibrachoa</i> hybrid	Liricashowers Deep Blue Imp.	*	*	NS
<i>Calibrachoa</i> hybrid	Starlette Trailing Purple	NS	NS	NS
<i>Calibrachoa</i> hybrid	Superbells Trailing Blue	NS	NS	NS
<i>Diascia</i> ×hybrida	Sunchimes Coral	NS	NS	NS
<i>Lantana camara</i>	Lucky Peach Sunrise	NS	NS	NS
<i>Lantana camara</i>	Lucky Lemon Cream	NS	NS	NS
<i>Nemesia</i> ×hybrida	Aromatica White	NS	*	NS
<i>Nemesia</i> ×hybrida	Vanilla Sachet	NS	NS	NS
<i>Petunia</i> ×hybrida	Cascadias Pink	NS	*	NS
<i>Petunia</i> ×hybrida	Suncatcher Pink	NS	NS	NS
<i>Sutera hybrida</i>	Bridal Showers	NS	NS	NS
<i>Sutera cordata</i>	Candy Floss Blue	NS	NS	NS

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

There was no effect of nitrogen toning on plant height, width index or number of flowers at harvest (Table 4). There was an interaction between shipping duration and postharvest time of measurement for number of flowers (Table 5 and Fig.1). There was no difference in the number of flowers on plants due to shipping duration at each time of measurement throughout postharvest. Plants shipped two days had a greater decrease in number of flowers than those shipped zero or one day thus the interaction. After two weeks all treatments had decreased to 2.2 flowers. After three weeks all flowers had abscised on all plants regardless of shipping duration.

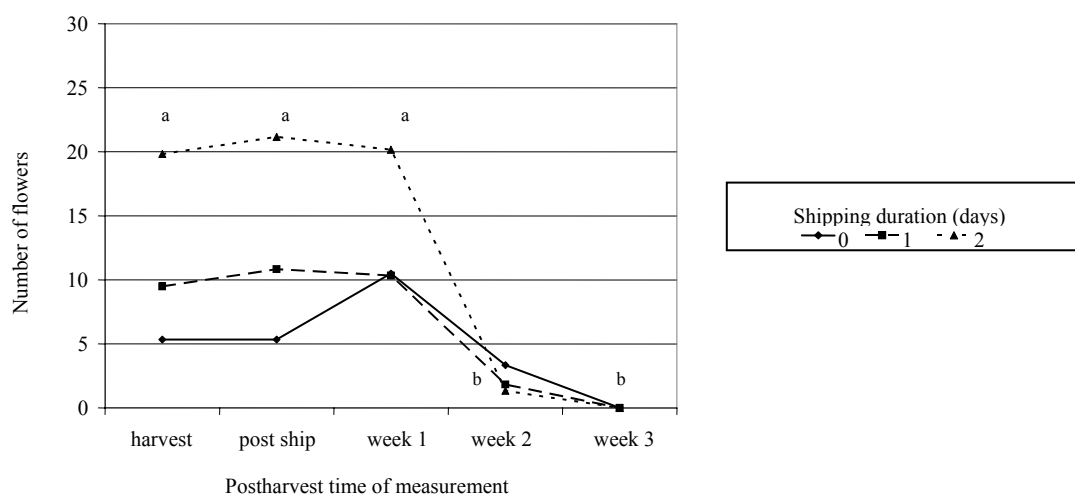


Fig. 1. Effect of shipping duration and postharvest time of measurement on number of individual flowers on *Angelonia angustifolia* ‘Caritas Lavender’. Mean separation within treatments (lowercase letters) by LSD at $P \leq 0.05$. There were no differences between treatments at each time of measurement.

Table 5. F-Test of repeated measure for effect of shipping duration on number of flowers.

Plant Species	Cultivar	Shipping		
		duration	Time	duration \times time
<i>Angelonia angustifolia</i>	Caritas Lavender	NS	***	**
<i>Argyranthemum frutescens</i>	Comet White	NS	***	NS
<i>Argyranthemum frutescens</i>	Sunlight	NS	***	NS
<i>Bracteantha bracteata</i>	Dreamtime Copper	NS	***	NS
<i>Bracteantha bracteata</i>	Dreamtime Cream	NS	***	**
<i>Bracteantha bracteata</i>	Florabella Gold	NS	***	NS
<i>Bracteantha bracteata</i>	Florabella White	NS	***	***
<i>Bracteantha bracteata</i>	Sundaze Bronze	NS	***	*
<i>Bracteantha bracteata</i>	Sundaze Golden Yellow	NS	NS	NS
<i>Calibrachoa</i> hybrid	Liricashowers Deep Blue Imp.	NS	***	NS
<i>Calibrachoa</i> hybrid	Starlette Trailing Purple	NS	***	NS
<i>Calibrachoa</i> hybrid	Superbells Trailing Blue	NS	***	NS
<i>Diascia</i> \times hybrida	Sunchimes Coral	*	***	**
<i>Lantana camara</i>	Lucky Peach Sunrise	NS	***	NS
<i>Lantana camara</i>	Lucky Lemon Cream	NS	***	NS
<i>Nemesia</i> \times hybrida	Aromatica White	NS	***	***
<i>Nemesia</i> \times hybrida	Vanilla Sachet	NS	***	NS
<i>Petunia</i> \times hybrida	Cascadias Pink	NS	***	NS
<i>Petunia</i> \times hybrida	Suncatcher Pink	NS	***	**
<i>Sutera hybrida</i>	Bridal Showers	**	***	**
<i>Sutera cordata</i>	Candy Floss Blue	NS	***	NS

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

Table 6. F-Test of repeated measure for effect of nitrogen toning on number of flowers.

Plant Species	Cultivar	Toning	Time	Toning \times time
<i>Angelonia angustifolia</i>	Caritas Lavender	NS	***	NS
<i>Argyranthemum frutescens</i>	Comet White	***	***	***
<i>Argyranthemum frutescens</i>	Sunlight	***	***	NS
<i>Bracteantha bracteata</i>	Dreamtime Copper	NS	**	NS
<i>Bracteantha bracteata</i>	Dreamtime Cream	*	***	NS
<i>Bracteantha bracteata</i>	Florabella Gold	*	***	**
<i>Bracteantha bracteata</i>	Florabella White	NS	***	NS
<i>Bracteantha bracteata</i>	Sundaze Bronze	NS	***	NS
<i>Bracteantha bracteata</i>	Sundaze Golden Yellow	NS	**	NS
<i>Calibrachoa</i> hybrid	Liricashowers Deep Blue Imp.	**	***	***
<i>Calibrachoa</i> hybrid	Starlette Trailing Purple	NS	***	**
<i>Calibrachoa</i> hybrid	Superbells Trailing Blue	NS	***	NS
<i>Diascia</i> \times hybrida	Sunchimes Coral	**	***	*
<i>Lantana camara</i>	Lucky Peach Sunrise	NS	***	NS
<i>Lantana camara</i>	Lucky Lemon Cream	NS	***	NS
<i>Nemesia</i> \times hybrida	Aromatica White	NS	***	NS
<i>Nemesia</i> \times hybrida	Vanilla Sachet	***	***	***
<i>Petunia</i> \times hybrida	Cascadias Pink	***	***	***
<i>Petunia</i> \times hybrida	Suncatcher Pink	NS	***	***
<i>Sutera hybrida</i>	Bridal Showers	**	***	***
<i>Sutera cordata</i>	Candy Floss Blue	NS	***	NS

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

Table 7. F-Test of repeated measure for effect of shipping duration on quality ratings.

Plant Species	Cultivar	Shipping		
		duration	Time	duration \times time
<i>Angelonia angustifolia</i>	Caritas Lavender	NS	***	NS
<i>Argyranthemum frutescens</i>	Comet White	***	***	***
<i>Argyranthemum frutescens</i>	Sunlight	NS	***	***
<i>Bracteantha bracteata</i>	Dreamtime Copper	NS	***	NS
<i>Bracteantha bracteata</i>	Dreamtime Cream	NS	***	NS
<i>Bracteantha bracteata</i>	Florabella Gold	NS	***	***
<i>Bracteantha bracteata</i>	Florabella White	NS	***	*
<i>Bracteantha bracteata</i>	Sundaze Bronze	*	***	**
<i>Bracteantha bracteata</i>	Sundaze Golden Yellow	NS	***	NS
<i>Calibrachoa</i> hybrid	Liricashowers Deep Blue Imp.	***	***	***
<i>Calibrachoa</i> hybrid	Starlette Trailing Purple	NS	***	NS
<i>Calibrachoa</i> hybrid	Superbells Trailing Blue	NS	***	NS
<i>Diascia</i> \times hybrida	Sunchimes Coral	*	***	*
<i>Lantana camara</i>	Lucky Peach Sunrise	NS	**	NS
<i>Lantana camara</i>	Lucky Lemon Cream	***	**	***
<i>Nemesia</i> \times hybrida	Aromatica White	NS	***	NS
<i>Nemesia</i> \times hybrida	Vanilla Sachet	NS	***	***
<i>Petunia</i> \times hybrida	Cascadias Pink	NS	***	NS
<i>Petunia</i> \times hybrida	Suncatcher Pink	***	***	***
<i>Sutera hybrida</i>	Bridal Showers	**	***	***
<i>Sutera cordata</i>	Candy Floss Blue	NS	***	NS

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

There was no effect due to nitrogen toning on number of flowers (Table 6).

Number of flowers increased from 15.5 at harvest to 20.0 one week postharvest. Similar to the shipping duration experiment, the number of flowers declined to 2.7 two weeks postharvest and 0.1 three weeks postharvest.

There was no difference in quality ratings due to shipping duration for ‘Caritas Lavender’, quality ratings declined significantly at each time of measurement (Tables 7 and 8). The quality remained high post ship but the quality declined to below marketable after one week postharvest due to lower leaf chlorosis on plants of all shipping durations. After two weeks the quality declined further due to flower abscission and lower leaf chlorosis.

There was no effect of nitrogen toning on quality ratings. They declined over the postharvest evaluation (Tables 8 and 9). They decreased to 3.44 after one week postharvest. The plants were no longer marketable after two weeks postharvest.

Table 8. Effect of postharvest time of measurement for experiment 1 (shipping duration) and 2 (production fertilization rate [nitrogen toning]) on quality rating of *Angelonia angustifolia*.

Experiment	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
1	5.00 a	4.83 b	2.89 c	2.06 d	1.78 e
2	5.00 a	-	3.44 b	2.00 c	1.61 d

Mean separation in rows by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

Table 9. F-Test of repeated measure for effect of nitrogen toning on quality ratings.

Plant Species	Cultivar	Toning	Time	Toning × time
<i>Angelonia angustifolia</i>	Caritas Lavender	NS	***	NS
<i>Argyranthemum frutescens</i>	Comet White	**	***	***
<i>Argyranthemum frutescens</i>	Sunlight	NS	***	NS
<i>Bracteantha bracteata</i>	Dreamtime Copper	NS	***	***
<i>Bracteantha bracteata</i>	Dreamtime Cream	***	***	***
<i>Bracteantha bracteata</i>	Florabella Gold	NS	***	***
<i>Bracteantha bracteata</i>	Florabella White	NS	***	NS
<i>Bracteantha bracteata</i>	Sundaze Bronze	NS	**	NS
<i>Bracteantha bracteata</i>	Sundaze Golden Yellow	NS	***	NS
<i>Calibrachoa</i> hybrid	Liricashowers Deep Blue Imp.	NS	***	NS
<i>Calibrachoa</i> hybrid	Starlette Trailing Purple	NS	***	*
<i>Calibrachoa</i> hybrid	Superbells Trailing Blue	NS	***	NS
<i>Diascia</i> ×hybrida	Sunchimes Coral	NS	***	*
<i>Lantana camara</i>	Lucky Peach Sunrise	NS	***	NS
<i>Lantana camara</i>	Lucky Lemon Cream	NS	***	NS
<i>Nemesia</i> ×hybrida	Aromatica White	**	***	**
<i>Nemesia</i> ×hybrida	Vanilla Sachet	***	***	***
<i>Petunia</i> ×hybrida	Cascadias Pink	***	***	***
<i>Petunia</i> ×hybrida	Suncatcher Pink	NS	***	NS
<i>Sutera hybrida</i>	Bridal Showers	**	***	***
<i>Sutera cordata</i>	Candy Floss Blue	**	***	***

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Angelonia ‘Caritas Lavender’ had similar results in both experiments. The number of flowers stayed the same or increased due to bud opening until after one week postharvest, they decreased after two weeks postharvest due to flower abscission. Quality declined after one week regardless of shipping or nitrogen toning.

Argyranthemum frutescens

Argyranthemum ‘Comet White’ and ‘Sunlight’ are two genetically and morphologically diverse cultivars. *Argyranthemum* ‘Comet White’ has a mounded habit with grey green leaves and single white daisy flowers. *Argyranthemum* ‘Sunlight’ has an upright-mounded habit with dark green leaves and yellow, single daisy flowers. ‘Comet White’ was harvested when the leaves covered the media; they averaged 25.22 cm tall, 21.85 cm wide and had three open flowers. ‘Sunlight’ was harvested when the leaves covered the media; they were 26.03 cm tall, 15.47 cm wide and had one open flower. Lower leaf chlorosis was seen on ‘Comet White’ after two weeks postharvest, the plants in experiment two had lower leaf necrosis after three weeks of postharvest evaluation (Table 3).

During the postharvest evaluation *Argyranthemum* ‘Sunlight’ displayed lower leaf chlorosis and bud abortion (Table 3). The lower leaf chlorosis occurred after two and three weeks postharvest with the chlorosis progressing to necrosis as time passed. Bud abortion occurred on mature buds after two weeks postharvest but was most evident after three weeks postharvest. The bud abortion occurred when the peduncle near the

receptacle base became necrotic followed by the developing petals becoming necrotic shortly thereafter.

At harvest there were height and width index differences in ‘Comet White’ but not ‘Sunlight’ due to nitrogen toning (Table 4). ‘Comet White’ plants receiving 100% PFR were shorter (24.08 cm) than those receiving 50% PFR (28.17 cm). Plants receiving 0% PFR were 26.25 cm tall and not different from either treatment. Plants treated with 100% PFR were wider (25.17 cm) than the plants receiving 0% PFR (19.46 cm). Plants receiving 50% PFR were 22.00 cm wide and not different from either treatment.

Table 10. Effect of postharvest time of measurement on number of flowers on *Argyranthemum frutescens* ‘Comet White’ and ‘Sunlight’ that were shipped.

Cultivar	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
Comet White	2.6 c	3.1 c	6.8 a	4.4 b	0.4 d
Sunlight	0.9 b	1.1 b	1.6 a	0.8 b	0.1 c

Mean separation in rows by LSD at $P \leq 0.05$

In experiment one there was no effect of shipping duration on number of flowers for either ‘Comet White’ or ‘Sunlight’ (Table 5). Postharvest time of measurement had an effect on number of flowers on both cultivars (Table 10). The number of flowers on ‘Comet White’ increased from 2.6 at harvest until one week postharvest when there was 6.8 flowers per plant. After two weeks the number of flowers decreased until there was

less than one flower per plant three weeks postharvest. The number of flowers on ‘Sunlight’ increased from 0.89 flowers at harvest to 1.6 flowers one week postharvest. The number of flowers decreased throughout the rest of the postharvest evaluation to almost no open flowers after three weeks postharvest.

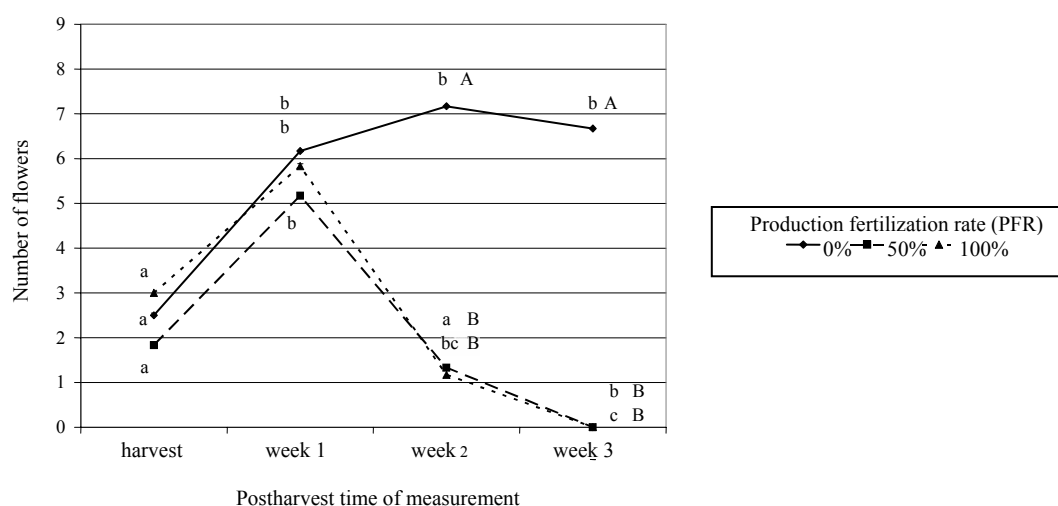


Fig 2. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on number of flowers on *Argyranthemum frutescens* ‘Comet White’. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

There was an interaction in number of flowers between nitrogen toning and postharvest time of measurement for ‘Comet White’ (Table 6). All plants had two flowers at harvest (Fig 2). The number of flowers increased on all treatments to an average of 5.7 flowers. Plants treated with 0% PFR maintained this number of flowers

for the rest of the postharvest evaluation. Plants that received 50% or 100% PFR decreased to an average of one flower after two weeks postharvest and had almost zero flowers after three weeks postharvest.

There were main effects of nitrogen toning and postharvest time of measurement on number of flowers on argyranthemum ‘Sunlight’ (Table 6). Plants toned with 0% PFR had 1.6 flowers while plants toned with 50% or 100% PFR had 0.6 flowers. The

Table 11. Effect of shipping duration and postharvest time of measurement on quality ratings of *Argyranthemum frutescens* ‘Comet White’ and ‘Sunlight’.

Cultivar	Shipping duration	Time of postharvest measurement				
	(days)	Harvest	Post ship	One week	Two weeks	Three weeks
Comet White	0	5.00 A a	5.00 A a	4.67 A a	2.67 A b	–
	1	5.00 A a	5.00 A a	5.00 A a	3.00 A b	–
	2	5.00 A a	5.00 A a	4.33 A a	2.67 A b	–
Sunlight	0	5.00 A a	5.00 A a	4.83 A a	3.67 A b	2.50 A c
	1	5.00 A a	5.00 A a	5.00 A a	3.50 A b	2.17 A c
	2	5.00 A a	4.00 B b	5.00 A a	3.50 A c	2.67 A d

Mean separation within cultivars in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

number of flowers increased from 1.1 flowers at harvest to 1.7 flowers after one week postharvest. The number of flowers decreased after two weeks postharvest to 0.6 flowers and 0.4 flowers after three weeks postharvest.

Both ‘Comet White’ and ‘Sunlight’ had an interaction between shipping duration and postharvest time of measurement for quality ratings (Tables 7 and 11). For ‘Comet White’ there were no differences between shipping treatments at each time of measurement. Plants shipped zero or two days were not marketable two weeks postharvest while plants shipped one day were marketable.

For ‘Sunlight’ there was a decrease in quality post ship for plants shipped for two days. This decrease in quality was no longer present after one week postharvest indicating the plants recovered after shipping. After three weeks postharvest none of the shipping treatments were marketable due to lower leaf necrosis and bud abortion.

Argyranthemum ‘Comet White’ had an interaction in quality rating between nitrogen toning and postharvest time of measurement due to a greater reduction in quality of the 0% PFR treated plants one week postharvest (Tables 9 and 12). All treatments were marketable for one week postharvest. Two weeks postharvest there was no statistical difference between treatments but the average quality rating for the 100% PFR treatment was still marketable while the other treatments had an average below our definition of marketable. The decrease in quality ratings was due to the decrease in number of flowers and lower leaf chlorosis on the plants. Three weeks postharvest none of the plants were marketable.

Table 12. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on quality ratings of *Argyranthemum frutescens* ‘Comet White’.

Cultivar	Production fertilization	Time of postharvest measurement			
	rate (%)	Harvest	One week	Two weeks	Three weeks
Comet White	0	5.00 A a	4.00 B b	2.67 A c	2.00 A d
	50	5.00 A a	4.67 AB a	2.67 A b	0.67 A c
	100	5.00 A a	4.83 A a	3.00 A b	0.83 A c

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

There was no effect of nitrogen toning on quality ratings of argyranthemum ‘Sunlight’ (Table 9). There was a postharvest time of measurement effect. Plants remained at a quality rating of 5.00 until one week postharvest. The quality rating decreased to 3.11 two weeks postharvest. ‘Sunlight’ was no longer marketable three weeks postharvest with a quality rating of 1.94.

From these experiments it can be concluded shipping did not affect the number of flowers on either ‘Comet White’ or ‘Sunlight’. There was an effect due to shipping on quality ratings for both cultivars but it was inconsistent and no firm conclusions can be made. The only effect of shipping seen over several measurements was on ‘Comet White’ plants shipped for one day. These plants had a higher quality than other shipping treatments. Nitrogen toning affected ‘Comet White’ height and width at harvest, toned plants were taller and narrower than those not toned. ‘Comet White’ plants toned with

0% PFR held their flowers longer postharvest than those toned with 50% or 100% PFR. ‘Sunlight’ had a main effect of toning on number of flowers. Plants toned with 0% PFR had one more flower than those toned with 50% or 100% PFR. Nitrogen toning did not beneficially increase the quality of ‘Comet White’ while ‘Sunlight’ plants had no toning effect on quality.

Bracteantha bracteata

The three bracteantha series grown had differences in appearance and habit. The cultivars from the Dreamtime series were compact and rosette-like in habit with green linear leaves; their flowers were held above the canopy. The Florabella series had a more upright habit with leaves that were larger than those on Dreamtime plants. They had grey green leaves with a rougher texture than the Dreamtime plants. The Sundaze series were upright and had more leaves than the other series. The leaves were dark green and smoother than those from the other series. The Sundaze series appeared to produce more vegetative growth before flowering than the other series did. Flowers were held just above canopy level. Plants of all series were harvested when leaves covered the media and there was one open flower or several mature buds visible on the plant. Lower leaf chlorosis and bud abortion were common postharvest decline symptoms in bracteantha (Table 3). Bud abortion began with a “bent neck” i.e. the peduncle curled and the bud was no longer held upright. It progressed when the receptacle turned necrotic and the bud subsequently failed to mature further.

Bracteantha ‘Dreamtime Copper’ displayed lower leaf chlorosis and bud abortion during the postharvest evaluation. The lower leaf chlorosis was minor two weeks postharvest but by three weeks postharvest many leaves were chlorotic or necrotic. Bud abortion was evident three weeks postharvest. Bracteantha ‘Dreamtime Cream’ had the same decline symptoms as ‘Dreamtime Copper’. These symptoms were not evident until three weeks postharvest. Lower leaf chlorosis occurred after two weeks postharvest and bud abortion after three weeks postharvest.

Bracteantha ‘Florabella Gold’ and ‘Florabella White’ displayed lower leaf chlorosis, bud abortion, internode elongation, and flower senescence. The lower leaf chlorosis and bud abortion were similar to previously described symptoms. Internode elongation occurred over the whole plant but primarily at the acropetal new growth. Flower senescence had a similar pattern as bud abortion. The first visible sign of senescence was a “bent neck” followed by necrosis of the peduncle at the base of the receptacle. A flower was considered senesced if this necrosis occurred prior to the release of seeds, if the seeds were released the flowers were considered old or mature flowers.

The postharvest decline symptoms Bracteantha ‘Sundaze Bronze’ and ‘Sundaze Golden Yellow’ displayed were lower leaf chlorosis and bud abortion. Plants in the Sundaze series lost quality rapidly postharvest. They appeared to be susceptible to disease problems postharvest.

At harvest, ‘Sundaze Bronze’ had height differences due to nitrogen toning (Table 4 and 13). Plants toned with 0% PFR were taller than those toned with 50% or

100% PFR. ‘Dreamtime Copper’, ‘Dreamtime Cream’, ‘Florabella Gold’, and ‘Florabella White’ had width index differences due to nitrogen toning. ‘Dreamtime Copper’ and

Table 13. Effect of production fertilization rate (nitrogen toning) on height and width index at harvest on *Bracteantha bracteata* cultivars.

Cultivar	Production fertilization rate (%)		
	0	50	100
Height (cm)			
Sundaze Bronze	28.58 a	25.17 b	25.08 b
Width Index (cm)			
Dreamtime Copper	17.71 b	20.33 a	18.42 b
Dreamtime Cream	19.38 b	22.75 a	21.42 ab
Florabella Gold	21.00 b	26.13 a	25.21 a
Florabella White	20.57 b	23.67 a	22.42 ab

Mean separation in rows by LSD at $P \leq 0.05$

‘Dreamtime Cream’ plants toned with 50% PFR were wider than those toned with 0% PFR. On ‘Dreamtime Copper’ the 50% PFR treatment was wider than those toned with 100% PFR while on ‘Dreamtime Cream’ there was no difference between plants treated with 50% and 100% PFR. ‘Florabella Gold’ plants in the 50% and 100% PFR treatments were wider than those in the 0% PFR treatment. On ‘Florabella White’ plants

toned with 50% PFR were wider than those toned with 0% PFR. Neither treatment was different from plants toned with 100% PFR.

In experiment one, bracteantha ‘Dreamtime Cream’, ‘Florabella White’, and ‘Sundaze Bronze’ had interactions between shipping duration and postharvest time of measurement for number of flowers (Table 5). ‘Dreamtime Copper’ and ‘Florabella Gold’ had effects on number of flowers due to postharvest time of measurement while ‘Sundaze Golden Yellow’ had no effects due to shipping duration or postharvest time of measurement on number of flowers. Throughout the postharvest evaluation ‘Sundaze Golden Yellow’ had a mean number of 0.61 flowers.

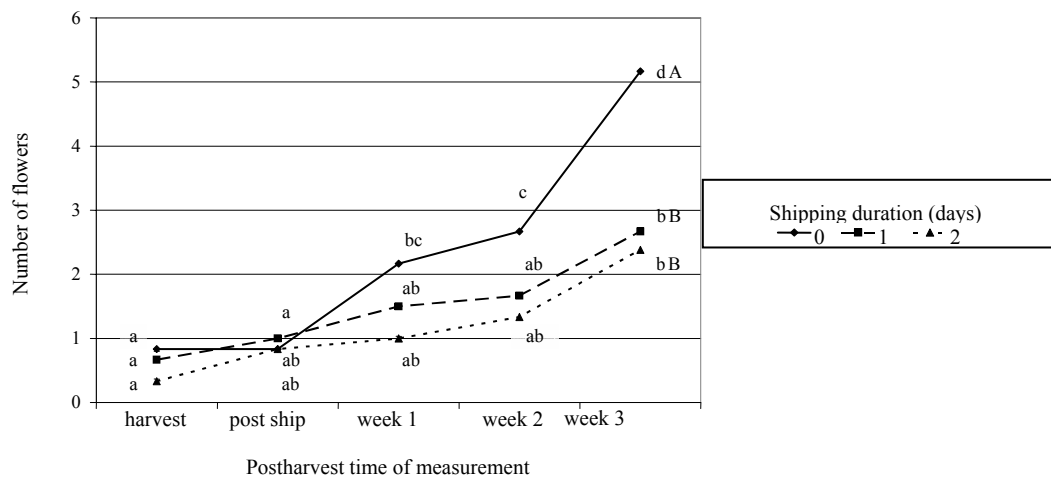


Fig 3. Effect of shipping duration and postharvest time of measurement on number of flowers on *Bracteantha bracteata* ‘Dreamtime Cream’. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

In ‘Dreamtime Cream’ the flowers continued to open through the evaluation regardless of the shipping treatment (Fig. 3). Number of flowers increased from harvest for plants shipped for one or two days to 2.7 and 2.4 flowers respectively three weeks postharvest. Plants that were not shipped increased from harvest to 5.2 flowers three weeks postharvest which was significantly greater than the other two treatments.

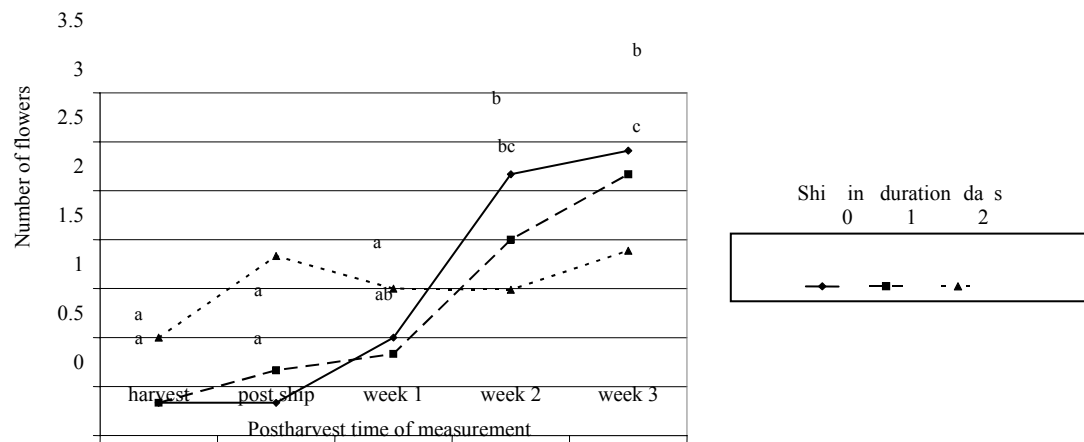


Fig 4. Effect of shipping duration and postharvest time of measurement on number of flowers on *Bracteantha bracteata* ‘Florabella White’. Mean separation within treatments (lowercase letters) by LSD at $P \leq 0.05$. There were no differences between treatments at each time of measurement.

In ‘Florabella White’ there was no difference in number of flowers between treatments during the postharvest evaluation (Fig. 4). However there were differences

within treatments. The number of flowers on plants shipped for two days stayed the same throughout the postharvest evaluation. Plants shipped for zero and one day increased from one week to three weeks postharvest. After three weeks postharvest they averaged between two and a half and three flowers per plant.

‘Sundaze Bronze’ had an interaction between shipping duration and postharvest time of measurement for number of flowers (Table 5). Plants shipped zero days increased in number of flowers until two weeks postharvest (Fig. 5). Plants shipped for one or two days did not change in number of flowers throughout the postharvest evaluation. There were no flowers on any plants after three weeks postharvest.

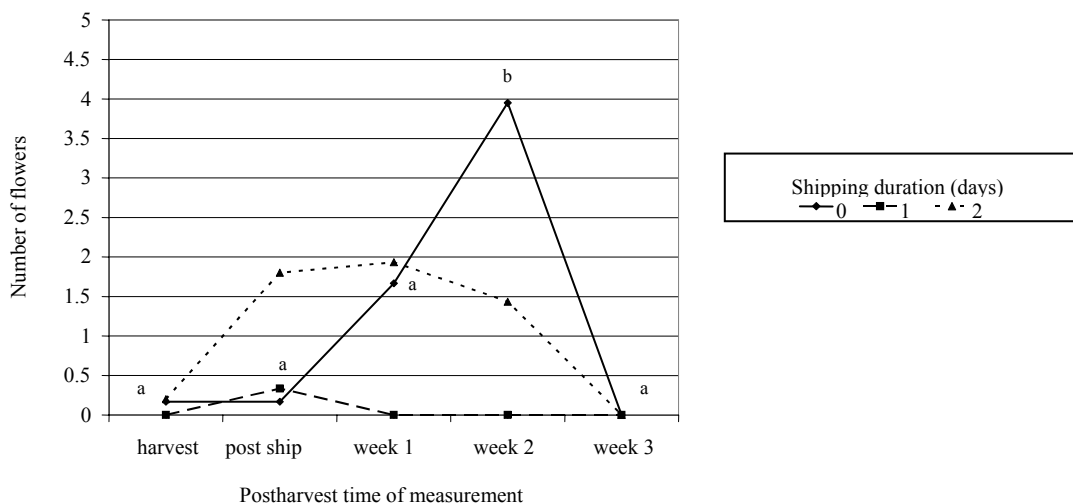


Fig. 5. Effect of shipping duration and postharvest time of measurement on number of flowers on *Bracteantha bracteata* ‘Sundaze Bronze’. Mean separation within treatments (lowercase letters) by LSD at $P \leq 0.05$. There were no differences between treatments at each time of measurement.

Table 14. Effect of postharvest time of measurement on number of flowers on *Bracteantha bracteata* cultivars that were shipped.

Cultivar	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
Dreamtime Copper	0.2 b	0.6 a	0.4 ab	0.4 ab	0.0 b
Florabella Gold	0.3 c	0.4 c	1.5 b	2.1 a	2.0 a

Mean separation in rows by LSD at $P \leq 0.05$.

In ‘Dreamtime Copper’ the number of flowers increased between harvest and post ship as mature buds opened (Table 14). The number of open flowers remained below 1.0 throughout the evaluation. The number of flowers was maintained through two weeks postharvest. It declined to no open flowers after three weeks postharvest.

As the evaluation progressed for ‘Florabella Gold’, the number of flowers increased from 0.3 flowers at harvest until there were 2.1 flowers on each plant two weeks postharvest (Table 14). The number of flowers remained the same through three weeks postharvest.

Bracteantha ‘Florabella Gold’ had an interaction between nitrogen toning and postharvest time of measurement on number of flowers (Table 6). ‘Dreamtime Cream’ had main effects of nitrogen toning and postharvest time of measurement. All other cultivars had no effect due to nitrogen toning but did have an effect due to postharvest time of measurement.

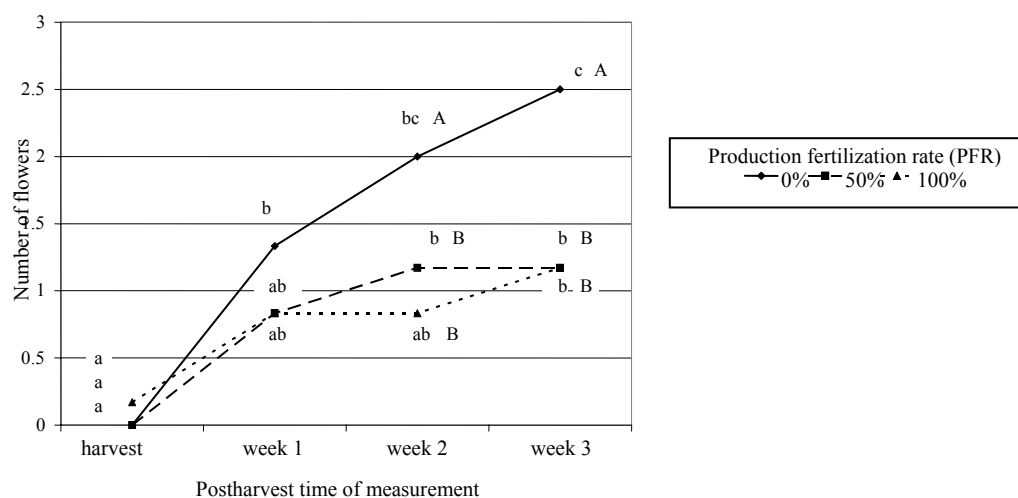


Fig 6. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on number of flowers on *Bracteantha bracteata* 'Florabella Gold'. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

The number of flowers on bracteantha 'Florabella Gold' increased throughout the postharvest evaluation for plants toned with 0% PFR (Fig. 6). Plants toned with 50% PFR increased until after two weeks postharvest. The plants toned with 100% PFR leveled off between one and two weeks postharvest but then increased after two weeks postharvest. At the end of postharvest evaluation, plants toned with 50% or 100% PFR had the same number of flowers and plants treated with 0% PFR had 1.3 more flowers than the other nitrogen toning treatments.

'Dreamtime Cream' had a main effect of nitrogen toning on number of flowers. Plants treated with 0% PFR had 1.3 flowers while plants toned with 50% and 100% PFR had 0.5 flowers.

Table 15. Effect of postharvest time of measurement on number of flowers on cultivars of *Bracteantha bracteata* that were nitrogen toned.

Cultivar	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
Dreamtime Copper	0.4a	0.7 a	0.4 a	0.1b
Dreamtime Cream	0.2 b	1.3 a	1.6 a	0.1 b
Florabella White	0.8 b	1.2 b	1.7 a	1.1 b
Sundaze Bronze	0.2 ab	0.6 a	0.0 b	0.0 b
Sundaze Golden Yellow	0.5 b	1.1 a	0.4 b	0.1 b

Mean separation in rows by LSD at $P \leq 0.05$.

On ‘Dreamtime Copper’ the number of flowers stayed the same between harvest and two weeks postharvest (Table 15). After this point the number of flowers decreased to 0.1 flowers after three weeks postharvest. ‘Dreamtime Cream’ increased in number of flowers until one week postharvest and at two weeks postharvest plants had 1.6 flowers per plant. Three weeks postharvest there were almost no open flowers on the plant due to flower maturation and premature flower senescence. ‘Florabella White’ also increased in number of flowers from harvest until two weeks postharvest. This increase was by almost one flower. Three weeks postharvest there was a slight decrease in number of flowers to 1.1 open flowers. ‘Sundaze Bronze’ decreased in number of flowers from harvest to two weeks postharvest. The plants never had one open flower per plant. Two and three weeks postharvest there were no flowers on any plants. On ‘Sundaze Golden Yellow’ the number of flowers increased from harvest to just over one

open flower one week postharvest. There were close to no open flowers two and three weeks postharvest.

‘Florabella Gold’, ‘Florabella White’ and ‘Sundaze Bronze’ had interactions between shipping duration and postharvest time of measurement on quality ratings (Table 7 and 16). In ‘Florabella Gold’ plants shipped for one day had a slight decrease in quality rating post ship, plants shipped for two days decreased to a rating of three post ship. Shipped plants had a lower quality rating post ship and two weeks postharvest, three weeks postharvest all plants were rated 3.33. Plants were still marketable at the end of postharvest evaluation. The increase in quality rating later in the evaluation may have been due to new flowers opening up on plants previously without an open flower.

‘Florabella White’ plants all declined in quality one week postharvest. All treatments were at the same quality two weeks postharvest and were marketable until three weeks postharvest.

‘Sundaze Bronze’ plants decreased in quality one week postharvest. Plants were not marketable then. Two weeks postharvest plants shipped for two days were higher in quality than those shipped for one day, three weeks postharvest plants shipped two days were higher in quality than those shipped zero or one day.

Table 16. Effect of shipping duration and postharvest time of measurement on quality ratings of *Bracteantha bracteata* cultivars.

Cultivar	Shipping duration (days)	Time of postharvest measurement				
		Harvest	Post ship	One week	Two weeks	Three weeks
Florabella Gold	0	5.00 A a	5.00 A a	3.17 A b	4.83 A a	3.33 A b
	1	5.00 A a	4.50 B b	2.83 A d	4.17 B b	3.33 A c
	2	5.00 A a	3.00 C c	3.00 A c	3.50 B b	3.33 A c
Florabella White	0	5.00 A a	5.00 A a	4.00 A b	3.67 A b	1.50 A c
	1	5.00 A a	4.67 A a	4.00 A b	4.00 A b	2.50 A c
	2	5.00 A a	5.00 A a	4.00 A b	3.33 A b	2.33 A c
Sundaze Bronze	0	5.00 A a	5.00 A a	2.17 A b	0.50 AB c	0.00 B c
	1	5.00 A a	4.50 A a	1.33 A b	0.00 B c	0.00 B c
	2	5.00 A a	4.17 A a	2.17 A b	1.17 A b	0.50 A c

Mean separation within cultivars in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

There were no shipping duration effects on quality rating of ‘Dreamtime Cream’, ‘Dreamtime Copper’ and ‘Sundaze Golden Yellow’. All three cultivars had an effect due to postharvest time of measurement (Table 17).

In ‘Dreamtime Copper’ the quality rating was unchanged post ship. It decreased after one week and again after two weeks postharvest. Plants were no longer marketable three weeks postharvest. Although it never opened more than 0.6 flowers, the mature

buds were healthy and could potentially open early in the evaluation. This positively affected the quality rating of the plants.

Table 17. Effect of postharvest time of measurement on quality ratings of *Bracteantha bracteata* cultivars that were shipped.

Cultivar	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
Dreamtime Copper	5.00 a	5.00 a	4.44 b	3.56 c	1.00 d
Dreamtime Cream	5.00 a	5.00 a	4.89 a	4.67 b	2.72 c
Sundaze Golden Yellow	5.00 a	5.00 a	2.67 b	0.89 c	0.06 d

Mean separation in rows by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

‘Dreamtime Cream’ quality declined two weeks postharvest. It did not decline below marketable until three weeks postharvest. The lack of quality decline can be attributed in part to the open flowers on the plants and a lack of lower leaf chlorosis throughout the evaluation.

‘Sundaze Golden Yellow’ plants decreased in quality one week postharvest when they were no longer marketable.

Table 18. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on quality ratings of *Bracteantha bracteata* cultivars.

Cultivar	Production	Time of postharvest measurement			
	fertilization rate (%)	Harvest	One week	Two weeks	Three weeks
Dreamtime Copper	0	5.00 A a	4.3 AB b	3.67 A c	0.83 A d
	50	5.00 A a	4.3 A b	2.50 A c	1.00 A d
	100	5.00 A a	3.5 B b	0.50 B c	0.00 A c
Dreamtime Cream	0	5.00 A a	4.83 A ab	4.33 A b	2.83 A c
	50	5.00 A a	4.67 A ab	4.50 A b	1.00 B c
	100	5.00 A a	4.83 A a	2.83 A b	0.83 B c
Florabella Gold	0	5.00 A a	2.33 B c	3.17 B b	3.17 A b
	50	5.00 A a	3.17 A b	3.33 AB b	2.67 B c
	100	5.00 A a	3.17 A bc	3.67 A b	2.83 A c

Mean separation within cultivars in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

There was an interaction between nitrogen toning and postharvest time of measurement on quality ratings of ‘Dreamtime Copper’, ‘Dreamtime Cream’ and ‘Florabella Gold’ (Tables 9 and 18). There was no effect due to nitrogen toning on ‘Florabella White’, ‘Sundaze Bronze’ or ‘Sundaze Golden Yellow’ but these cultivars had an effect due to postharvest time of measurement.

The ‘Dreamtime Copper’ plants toned with 100% PFR had a lower quality rating compared to those toned with 0% PFR one week postharvest (Table 18). Two weeks postharvest the 0% PFR treatment was the only one still marketable although there was no difference between the 0% and 50% PFR treatments. Three weeks postharvest there were no living plants in the 100% PFR treatment.

‘Dreamtime Cream’ plants in the 100% PFR treatment were not marketable two weeks postharvest. The other treatments were still at a high quality two weeks postharvest but none of the treatments were marketable three weeks postharvest.

The quality ratings of ‘Florabella Gold’ decreased to below marketable after one week postharvest for plants toned with 0% PFR. Two weeks postharvest the ratings of this treatment increased to above three where it remained for the rest of the postharvest evaluation. The ratings of plants toned with 50% or 100% PFR decreased one week postharvest and remained at this level until two weeks postharvest. Plants toned with 50% and 100% PFR were not marketable three weeks postharvest while plants toned with 0% PFR were still marketable.

On ‘Florabella White’ the quality ratings decreased between harvest and one week postharvest (Table 19). They then remained unchanged until three weeks postharvest when the plants were no longer marketable. On ‘Sundaze Bronze’ the quality decreased one week postharvest and the plants were no longer marketable at that point in time. The quality ratings of ‘Sundaze Golden Yellow’ decreased one week postharvest to slightly more than a rating of three. Two weeks postharvest the plants were no longer marketable.

Table 19. Effect of postharvest time of measurement on quality ratings of cultivars of *Bracteantha bracteata* that were nitrogen toned.

Cultivar	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
Florabella White	5.00 a	4.00 b	3.94 b	2.11 c
Sundaze Bronze	5.00 a	2.33 b	0.39 c	0.00 d
Sundaze Golden Yellow	5.00 a	3.33 b	1.00 c	0.17 d

Mean separation in rows by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

The bracteantha cultivars reacted differently to shipping duration and nitrogen toning. ‘Dreamtime Copper’ and ‘Sundaze Golden Yellow’ had no effect due to shipping duration on number of flowers or quality rating. ‘Florabella White’, ‘Sundaze Bronze’, and ‘Sundaze Golden Yellow’ had no effect due to nitrogen toning on quality rating. ‘Dreamtime Cream’ opened flowers during the postharvest evaluation with plants shipped zero days opening more flowers than those shipped one or two days. ‘Florabella White’ plants shipped zero or one days opened flowers during the evaluation with no difference between the shipping durations. ‘Florabella Gold’ opened flowers during the evaluation with no effect due to shipping duration. ‘Sundaze Bronze’ opened flowers early in the evaluation before decreasing to no flowers after three weeks.

‘Florabella Gold’ and ‘Dreamtime Cream’ were the only cultivars with number of flowers affected by nitrogen toning. ‘Florabella Gold’ toning treatments all increased in flower number through the evaluation but plants toned with 0% PFR opened more

flowers than the other toning treatments two and three weeks postharvest. ‘Dreamtime Cream’ plants toned with 0% PFR had more flowers than other toning treatments.

‘Dreamtime Cream’, ‘Florabella White’, ‘Sundaze Golden Yellow’ increased in number of flowers early in the evaluation before having less flowers at the end. ‘Dreamtime Copper’ maintained its number of flowers until three weeks postharvest and ‘Sundaze Bronze’ maintained its number of flowers until two weeks postharvest when it had no flowers.

‘Dreamtime Copper’, ‘Dreamtime Cream’, and ‘Florabella White’ remained marketable until three weeks postharvest regardless of shipping duration. ‘Florabella Gold’ plants shipped for one day had a quality rating of less than 3.00 one week postharvest, the rating then increased and all treatments were marketable until the end of the evaluation. ‘Sundaze Bronze’ and ‘Sundaze Golden Yellow’ were no longer marketable one week postharvest due to the decline symptoms of the vegetative tissue.

Nitrogen toning affected quality rating and marketability of ‘Dreamtime Copper’, ‘Dreamtime Cream’ and ‘Florabella Gold’. ‘Dreamtime Copper’ plants treated with 50% or 100% PFR were not marketable two weeks postharvest while those toned with 0% were marketable until three weeks postharvest. ‘Dreamtime Cream’ plants treated with 100% PFR were not marketable two weeks postharvest while those toned with 50% or 0% PFR were marketable until three weeks postharvest. ‘Florabella Gold’ plants treated with 0% PFR were not marketable one week postharvest but the quality rating increased to above 3.00 two weeks postharvest and remained marketable through the evaluation. Plants treated with 50% and 100% PFR were not marketable three weeks

postharvest. ‘Sundaze Bronze’ was not marketable one week postharvest, ‘Sundaze Golden Yellow’ was not marketable two weeks postharvest while ‘Florabella White’ was marketable until three weeks postharvest.

Compared to the effects of nitrogen toning on bracteantha growth, the effects of shipping duration appear minor and not of much concern. Nitrogen toning appears to affect bracteantha growth more. Most of the species had height and width index differences due to toning concentration. Nitrogen toning affected the quality of three of the cultivars tested while it affected the flower number of only one cultivar.

‘Sundaze Bronze’ and ‘Sundaze Golden Yellow’ had short shelf lives. This was due in part to disease problems in the vegetative tissues of the plants. They had excessive amounts of vegetative growth which decreased air circulation between plants before and after harvest. Further research into decreasing vegetative growth of these cultivars would be useful.

Calibrachoa hybrid

The calibrachoa cultivars grown were similar in morphology and all were trailing cultivars with small, medium green leaves and dark purple flowers. They were harvested when the leaves covered the media and there were several open flowers on the plants.

Calibrachoa ‘Liricashowers Deep Blue Imp.’ was 22.56 cm tall, 38.38 cm wide, and had 10.1 open flowers when harvested. It displayed many postharvest decline symptoms (Table 3). These symptoms appeared over the duration of the evaluation.

Lower leaf chlorosis was noted about halfway through the evaluation. The lower leaves of the plant turned chlorotic and then necrotic. This progressed acropetally up the plant through the rest of the evaluation. Internode elongation was noted on the acropetal tips where the internodes grew longer and tended to curl compared to the straight stems seen on the plants at harvest. Flower color fading occurred on flowers that opened during the evaluation. They became lighter purple in color or streaked with white compared to the solid dark purple flower this cultivar typically has. Flower size was decreased on flowers that opened during the postharvest evaluation. These flowers were about half the size normally expected on this cultivar and often displayed color fading as well as the size decrease. Stem die back occurred late in the evaluation. Necrosis was noted on the stems starting at the acropetal tips and moving basally down the stems.

Calibrachoa ‘Starlette Trailing Purple’ plants were 15.31 cm tall, 33.00 cm wide and had 17.8 flowers at harvest. The postharvest decline symptoms displayed during this evaluation were lower leaf chlorosis, internode elongation, and flower senescence. Lower leaf chlorosis and internode elongation presented in a similar manner to ‘Liricashower Deep Blue Imp.’ Flower senescence occurred when flowers turned necrotic before they were fully open and the petals were necrotic upon opening.

Calibrachoa ‘Superbells Trailing Blue’ plants were 18.72 cm tall, 35.90 cm wide and had 8.3 flowers at harvest. They displayed lower leaf chlorosis, internode elongation, flower color fading, and flower size decrease as postharvest decline symptoms. These symptoms were displayed in a similar manner as those described with other calibrachoa cultivars.

At harvest there were height and width index differences in ‘Liricashowers Deep Blue Imp.’ due to nitrogen toning, these differences were not seen on ‘Starlette Trailing Purple’ or ‘Superbells Trailing Blue’ (Table 4). ‘Liricashowers Deep Blue Imp.’ plants receiving 50 % and 100% PFR (Production Fertilization Rate) were shorter (17.25 and 17.92 cm) than those receiving 0% PFR (22.50 cm). Plants treated with 50% and 100% PFR were wider (45.54 and 46.21 cm) than the plants receiving 0% PFR (36.63 cm).

There was no shipping effect on number of flowers for any calibrachoa cultivar (Tables 5 and 20). The number of flowers on ‘Liricashowers Deep Blue Imp.’ increased from 10.1 flowers at harvest to 17.4 flowers after one week postharvest. The number then declined to 2.5 flowers after two weeks and 0.1 flowers after three weeks

Table 20. Effect of postharvest time of measurement on number of flowers on

Calibrachoa hybrid ‘Liricashowers Deep Blue Imp.’, ‘Starlette Trailing Purple’ and ‘Superbells Trailing Blue’ that were shipped.

Cultivar	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
Liricashower Deep Blue Imp.	10.1 b	10.6 b	17.4 a	2.5 c	0.1c
Starlette Trailing Purple	18.9 a	17.1a	21.5 a	22.9 a	0.3 b
Superbells Trailing Blue	8.3 a	7.8 a	0.4 b	0.0 b	0.3 b

Mean separation in rows by LSD at $P \leq 0.05$

postharvest. ‘Starlette Trailing Purple’ had 22.9 flowers after two weeks postharvest the number of flowers then decreased to 0.3 flowers three weeks postharvest. ‘Superbells Trailing Blue’ retained its flowers from harvest to post ship. After one week postharvest the number of flowers decreased to 0.4 where it remained for the rest of the evaluation.

There was an interaction for number of flowers between nitrogen toning and postharvest time of measurement for ‘Liricashowers Deep Blue Imp.’ and ‘Starlette Trailing Purple’ (Table 6). ‘Superbells Trailing Purple’ did not have an effect on number of flowers due to nitrogen toning treatment but there was an effect due to postharvest time of measurement.

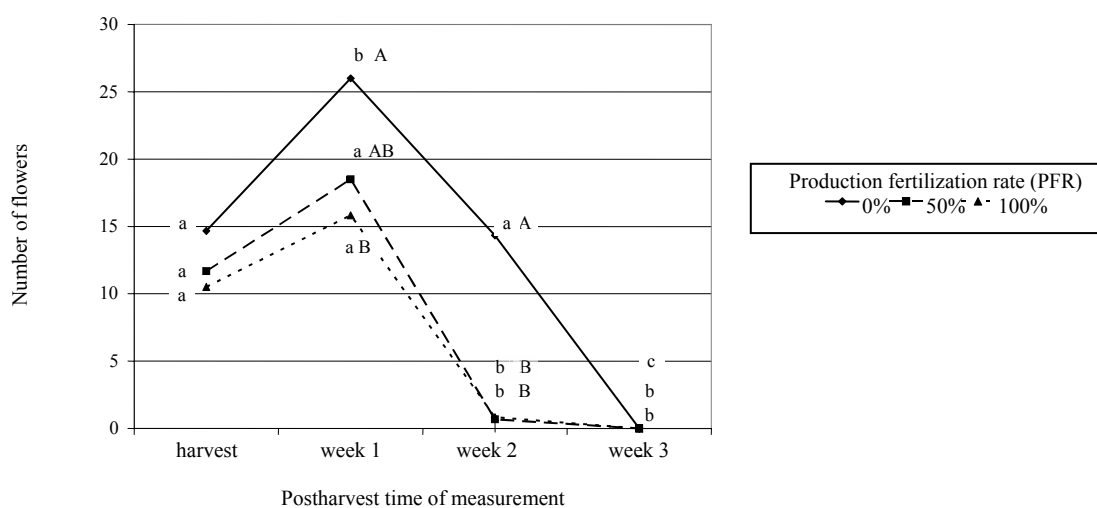


Fig. 7. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on number of flowers on *Calibrachoa* hybrid ‘Liricashowers Deep Blue Imp.’ Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

‘Liricashowers Deep Blue Imp.’ plants toned with 0% PFR had more flowers than the plants treated with 100% PFR one week postharvest (Fig. 7). Two weeks postharvest plants treated with 0% PFR had more flowers than the other treatments. Plants toned with 50% and 100% PFR followed a similar trend. They declined to close to zero two weeks postharvest. None of the plants had flowers after three weeks postharvest.

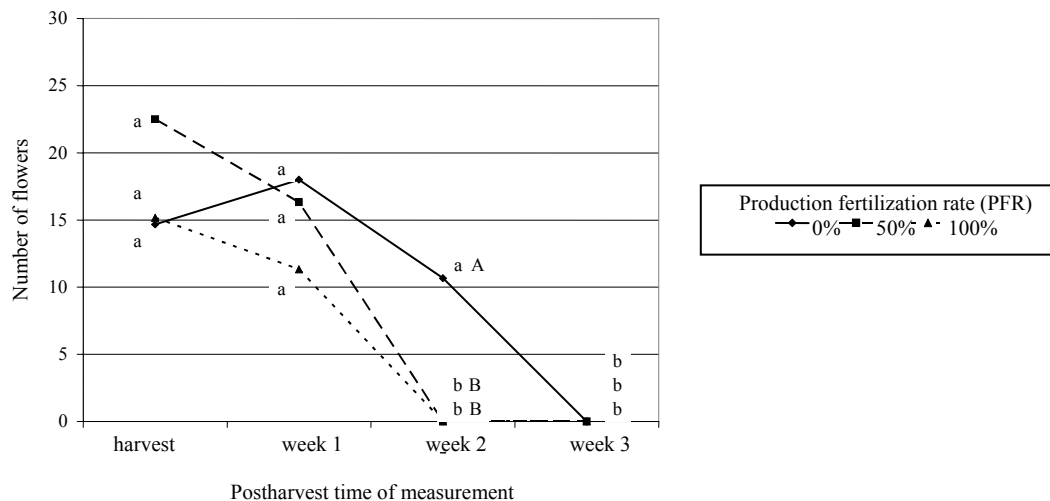


Fig. 8. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on number of flowers on *Calibrachoa* hybrid 'Starlette Trailing Purple'. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

For ‘Starlette Trailing Purple’ the number of flowers decreased over time (Fig 8). Plants treated with 50% and 100% PFR had no flowers after two weeks postharvest while those treated with 0% PFR retained their flowers until three weeks postharvest. None of the treatments had flowers three weeks postharvest.

‘Superbells Trailing Blue’ had 7.2 flowers at harvest. By one week postharvest the number of flowers had dropped to 0.2. This number remained at zero for the rest of the evaluation.

There was an interaction in quality ratings between shipping duration and postharvest time of measurement for ‘Liricashowers Deep Blue Imp.’ (Table 7).

‘Starlette Trailing Purple’ and ‘Superbells Trailing Blue’ had no effect due to shipping duration. There was an effect due to postharvest time of measurement on these two cultivars.

Table 21. Effect of shipping duration and postharvest time of measurement on quality ratings of *Calibrachoa* hybrid ‘Liricashowers Deep Blue Imp.’

Shipping duration	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
0 days	5.00 A a	5.00 A a	4.00 A b	2.67 A c	2.00 AB c
1 day	5.00 A a	4.00 A b	4.00 A b	2.67 A c	2.83 A c
2 days	5.00 A a	4.00 A b	3.83 A b	2.00 B c	1.33 B d

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

‘Liricashowers Deep Blue Imp.’ plants shipped for one or two days decreased to a quality rating of four after shipping (Table 21). One week postharvest there was no difference between shipping treatments but they had a decrease in quality from harvest. Two weeks postharvest plants shipped for two days had a lower rating than the other shipping durations. None of the treatments were marketable after two weeks postharvest due to lower leaf necrosis and flower senescence.

The quality of ‘Starlette Trailing Purple’ plants did not change until two weeks postharvest when it declined to 4.06 due to lower leaf chlorosis (Table 22). After three weeks postharvest, quality declined to below marketable due to flower senescence and lower leaf necrosis. The quality of ‘Superbells Trailing Blue’ decreased one week postharvest due to flower senescence and internode elongation and the plants were no longer marketable after two weeks postharvest due to flower senescence, internode elongation and lower leaf chlorosis.

Table 22. Effect of postharvest time of measurement on quality ratings of *Calibrachoa* hybrid ‘Starlette Trailing Purple’ and ‘Superbells Trailing Blue’ that were shipped.

Cultivar	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
Starlette Trailing Purple	5.00 a	5.00 a	5.00 a	4.06 b	2.28 c
Superbells Trailing Blue	5.00 a	5.00 a	4.06 b	2.69 c	1.06 d

Mean separation in rows by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

‘Starlette Trailing Purple’ had an interaction between nitrogen toning and postharvest time of measurement for quality rating (Table 9). ‘Liricashowers Deep Blue Imp.’ and ‘Superbells Trailing Blue’ did not have differences in quality due to toning treatment; they had differences in quality due to postharvest time of measurement.

For ‘Starlette Trailing Purple’ the quality ratings were unchanged until two weeks postharvest (Table 23). Two weeks postharvest plants treated with 0% PFR were the only ones still marketable because the other treatments did not have flowers. By three weeks postharvest none of the plants were marketable due to flower senescence and lower leaf chlorosis and necrosis.

Table 23. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on quality ratings of *Calibrachoa* hybrid ‘Starlette Trailing Purple’.

Production fertilization rate	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
0%	5.00 A a	5.00 A a	3.67 A b	1.83 A c
50%	5.00 A a	5.00 A a	2.33 B b	1.83 A b
100%	5.00 A a	5.00 A a	2.67 B b	1.83 A c

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

Table 24. Effect of postharvest time of measurement on quality ratings of *Calibrachoa* hybrid ‘Liricashowers Deep Blue Imp.’ and ‘Superbells Trailing Blue’ that were nitrogen toned.

Cultivar	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
Liricashowers Deep Blue Imp.	5.00 a	4.06 b	2.78 c	1.50 d
Superbells Trailing Blue	5.00 a	3.94 b	0.94 c	0.50 d

Mean separation in rows by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

The quality ratings decreased to below marketable two weeks postharvest for both ‘Liricashowers Deep Blue Imp.’ and ‘Superbells Trailing Blue’ due to flower senescence and lower leaf chlorosis and necrosis (Table 24). The quality ratings continued to decrease due to stem die back along with symptoms already listed.

There was no effect of shipping duration on number of flowers on any calibrachoa cultivar. Two days of shipping decreased the quality but not the marketability of ‘Liricashowers Deep Blue Imp.’ while shipping did not affect the quality of the other cultivars. Toning with 0% PFR maintained the number of flowers on ‘Liricashowers Deep Blue Imp.’ and ‘Starlette Trailing Purple’ while there was no effect of toning on number of flowers of ‘Superbells Trailing Blue’. Toning with 0% PFR held quality longer than plants toned with 50% and 100% PFR on ‘Starlette Trailing Purple’ while there was no effect due to toning on the other cultivars. Overall, ‘Superbells Trailing Blue’ did not display an effect due to either shipping duration or nitrogen

toning. ‘Liricashowers Deep Blue Imp.’ seemed to be the most responsive cultivar to shipping while ‘Starlette Trailing Purple’ was the most responsive to toning and had a longer shelf life.

Diascia ×hybrida

Only one cultivar of diascia was grown for these experiments. Diascia ‘Sunchimes Coral’ is a trailing plant with small, dark green, crenate leaves. Its flowers are small and deep coral in color. Plants were harvested when they were 21.39 cm tall and 17.78 cm wide. The leaves covered the media and there were six racemes with open flowers on the plants at harvest. Their postharvest decline symptoms were lower leaf chlorosis, flower color fading, and stem dieback (Table 3). The lower leaves had a few chlorotic spots which progressed to the entire leaf turning chlorotic. The flowers faded to a pale cream color and the stems turned necrotic from the base. Stems on the periphery of the plant tended to die first.

There were no effects of nitrogen toning on plant height, width index, or number of flowers at harvest (Table 4). There was an interaction between shipping duration and postharvest time of measurement for number of flowers (Table 5). There was no difference in number of flowers between shipping duration treatments at harvest (Fig. 9). After shipping plants shipped one day had fewer flowers than plants shipped for zero or two days. One week postharvest plants shipped for zero or two days decreased in number of flowers and all treatments had the same number of flowers. Two weeks postharvest the number of flowers decreased to zero regardless of shipping duration.

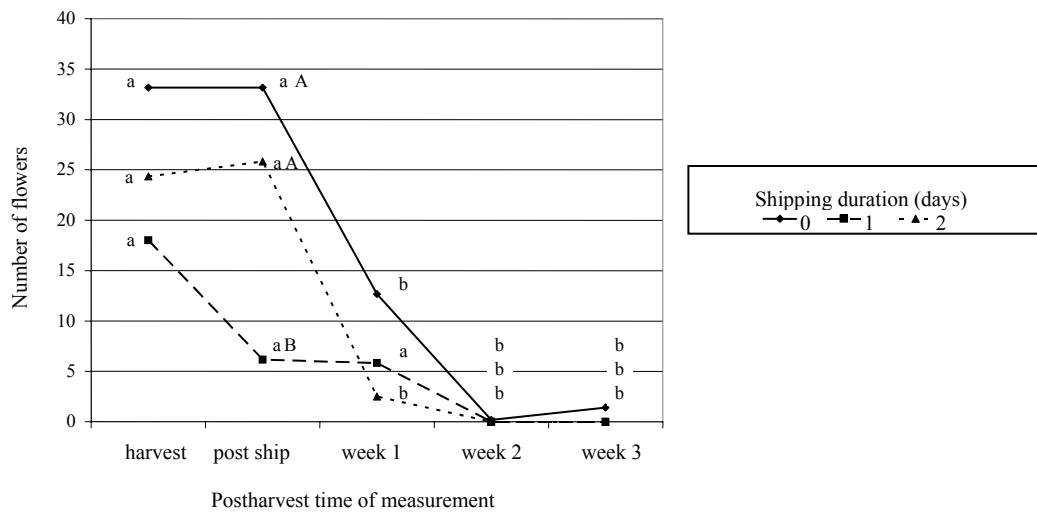


Fig 9. Effect of shipping duration and postharvest time of measurement on number of flowers on *Diascia* \times *hybrida* 'Sunchimes Coral'. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

There was an interaction between nitrogen toning and postharvest time of measurement for number of flowers (Table 6 and Fig. 10). The plants toned with 50% PFR had fewer flowers than the plants toned with 100% PFR but neither treatment was different from the 0% PFR treatment one week postharvest. None of the treatments had flowers two weeks postharvest.

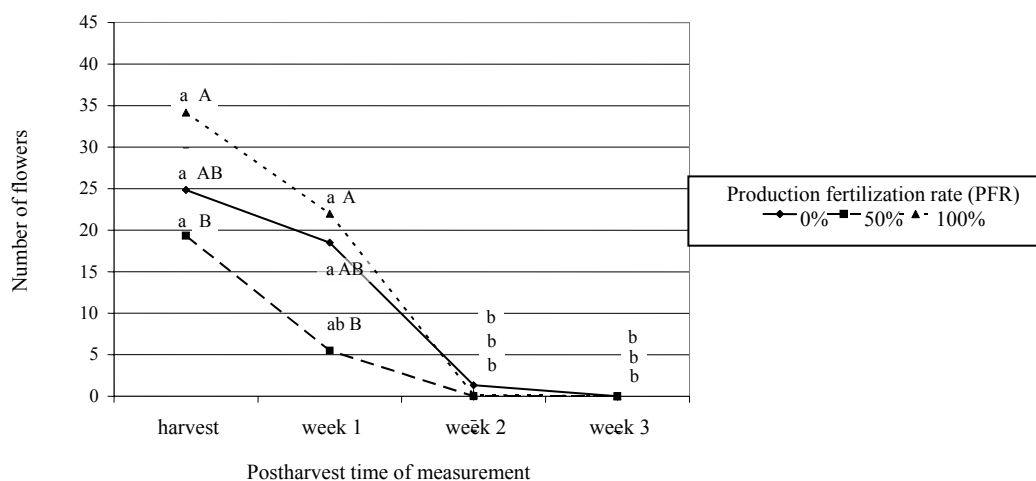


Fig 10. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on number of flowers on *Diascia* \times *hybrida* 'Sunchimes Coral'. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

Table 25. Effect of shipping duration and postharvest time of measurement on quality ratings of *Diascia* \times *hybrida* 'Sunchimes Coral'.

Shipping duration	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
0 days	5.00 A a	3.17 A b	2.83 AB b	1.83 AB c
1 day	5.00 A a	3.83 A b	3.33 A c	2.33 A d
2 days	5.00 A a	2.17 B b	1.17 B c	1.17 B d

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

There was an interaction between shipping duration and postharvest time of measurement for quality rating of diascia ‘Sunchimes Coral’ (Tables 7 and 25). The quality ratings decreased for all treatments one week postharvest but plants shipped for zero or one day had a higher quality than those shipped for two days. Plants shipped for two days were not marketable after one week postharvest due to decline symptoms in the vegetative tissue. Plants shipped for zero or one day were marketable after two weeks postharvest. No plants were considered marketable after three weeks postharvest.

Table 26. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on quality ratings of *Diascia ×hybrida* ‘Sunchimes Coral’.

Production fertilization rate	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
0%	5.00 A a	3.17 AB b	1.83 AB c	0.67 A d
50%	5.00 A a	2.83 B b	1.00 B c	0.67 A c
100%	5.00 A a	3.67 A b	2.83 A c	1.67 A d

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

There was an interaction between nitrogen toning and postharvest time of measurement for quality ratings (Tables 9 and 26). Plants that received 50% PFR were not marketable one week postharvest. None of the treatments were marketable two weeks postharvest.

Diascia had a shelf life of one week in the shipping duration and nitrogen toning evaluations. Postharvest decline was due to leaf chlorosis and necrosis and stem necrosis. Two weeks postharvest flower senescence contributed to the postharvest quality decline. Plants shipped for one day had fewer flowers post ship than those shipped for zero or two days but by one week postharvest there were no differences between the treatments. In contrast the quality ratings of plants shipped for one day had a higher quality than the other treatments. This indicates the quality of the other treatments decreased due to the decline symptoms seen on the vegetative tissue. Nitrogen toning did not have a positive impact on diascia. Plants at 100% PFR had a higher quality than the other treatments through the evaluation and had more flowers one week postharvest. These results indicate more research into shipping effects could be conducted.

Lantana camara

Lantana ‘Lucky Lemon Cream’ and ‘Lucky Peach Sunrise’ both had an upright trailing habit and dark green crenate leaves but different flower colors. ‘Lucky Lemon Cream’ flowers had pale yellow centers while the petal tips were darker yellow. ‘Lucky Peach Sunrise’ flowers had orange centers with pink petal tips. ‘Lucky Lemon Cream’ was harvested when it was 26.86 cm tall, had a width index of 27.18, and 6.5 open flowers. ‘Lucky Peach Sunrise’ was 25.81 cm tall, had a width index of 25.33 cm and had 2.6 open flowers at harvest. The only decline symptom shown by the lantana

cultivars was flower senescence (Table 3). Flower senescence occurred when flowers within the umbel abscised immediately after opening.

Nitrogen toning did not affect plant height, width index, or number of flowers at harvest for either cultivar (Table 4). There were no effects of shipping duration or nitrogen toning on number of flowers for either lantana cultivars (Tables 5 and 6). All differences were due to postharvest time of measurement. Regardless of shipping duration the number of flowers on ‘Lucky Lemon Cream’ which had 6.5 flowers at harvest decreased over time to 0.1 flowers by two weeks postharvest (Table 27). ‘Lucky Peach Sunrise’ number of flowers decreased from 2.6 flowers at harvest to 0.1 flowers three weeks postharvest.

Table 27. Effect of postharvest time of measurement on number of flowers on *Lantana camara* cultivars that were shipped.

Cultivar	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
Lucky Lemon Cream	6.5 a	5.1 a	0.5 b	0.1 b	0.1 b
Lucky Peach Sunrise	2.6 ab	2.8 a	1.3 bc	0.2 c	0.1 c

Mean separation in rows by LSD at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

Regardless of nitrogen toning treatment, the number of flowers on ‘Lemon Cream’ decreased from five flowers to zero flowers by two weeks postharvest (Table

28). ‘Lucky Peach Sunrise’ decreased in flowers from two to less than one in one week. By two weeks postharvest there were no flowers on the plants.

There was an interaction between shipping duration and postharvest time of measurement on the quality rating of ‘Lucky Lemon Cream’ (Tables 7 and 29). ‘Lucky Peach Sunrise’ had a main effect of postharvest time of measurement.

Table 28. Effect of postharvest time of measurement on number of flowers on *Lantana camara* cultivars that were nitrogen toned.

Cultivar	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
Lucky Lemon Cream	5.4 a	1.6 b	0.1 b	0.0 b
Lucky Peach Sunrise	2.3 a	0.3 b	0.0 c	0.2 c

Mean separation in rows by LSD at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

Table 29. Effect of shipping duration and postharvest time of measurement on quality ratings of *Lantana camara* ‘Lucky Lemon Cream’.

Shipping duration	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
0 days	5.00 A a	5.00 A a	3.67 B b	2.33 B c	1.67 B d
1 day	5.00 A a	5.00 A a	4.33 A b	2.67 AB c	2.67 AB c
2 days	5.00 A a	4.17 B b	4.00 AB b	4.00 A b	4.17 A b

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

‘Lucky Lemon Cream’ plants shipped for two days had a decrease in quality post ship. Plants shipped for zero or one day maintained a quality of 5.00 until one week postharvest. Two weeks postharvest plants shipped for zero or one day were no longer marketable while plants shipped for two days were marketable throughout the entire evaluation.

‘Lucky Peach Sunrise’ was marketable throughout the entire evaluation because it stayed green even though it was without flowers. Quality decreased from 5.00 at harvest to 4.39 one week postharvest. Two weeks postharvest the plants had a quality rating of 4.00 and three weeks postharvest they were rated 3.67.

There was no effect of nitrogen toning on quality ratings of ‘Lucky Lemon Cream’ or ‘Lucky Peach Sunrise’ (Table 9). ‘Lucky Lemon Cream’ plants decreased in quality one and two weeks postharvest (Table 30). By two weeks postharvest the plants could not be considered marketable. ‘Lucky Peach Sunrise’ had similar trends as experiment one, remaining marketable throughout the entire evaluation.

Table 30. Effect of postharvest time of measurement on quality ratings of *Lantana camara* cultivars that were nitrogen toned.

Cultivar	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
Lucky Lemon Cream	5.00 a	4.00 b	1.94 c	1.11 d
Lucky Peach Sunrise	5.00 a	4.83 b	4.06 c	3.83 c

Mean separation in rows by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

From these results it appears ‘Lucky Peach Sunrise’ had no effect due to shipping duration and neither cultivar of lantana is affected by nitrogen toning. No major problems with the foliage were seen on these plants but flower abscission was seen one and two weeks postharvest with no new flowers opening on the plant in the postharvest environment. Further studies on preventing floral abscission could be conducted.

Nemesia ×hybrida

Nemesia cultivars used were upright with small dark green leaves with crenate margins. The flowers were white and borne on a raceme. ‘Aromatica White’ was harvested when it was 31.89 cm tall, with a 20.69 cm width index, and 46.1 open flowers on 12.4 racemes. ‘Vanilla Sachet’ was harvested when it was 27.08 cm tall, with a width index of 19.26 cm, and 16.1 open flowers on 7.2 racemes. Both cultivars displayed lower leaf chlorosis and internode elongation during the postharvest evaluation (Table 3). The internode elongation occurred at the acropetal end of stems and between flowers on the racemes.

At harvest, there was a width difference between nitrogen toning treatments on ‘Aromatica White’, no differences due to nitrogen toning were seen on ‘Vanilla Sachet’ (Table 4). Plants treated with 50% and 100% PFR were wider at harvest than plants treated with 0% PFR.

There was an interaction between shipping duration and postharvest time of measurement on number of flowers on *nemesia* ‘Aromatica White’ (Table 5 and Fig. 11). Plants shipped zero and one day followed a similar trend. There was no flower loss

post ship but there were no flowers on the plants one week postharvest. Plants shipped two days had less than half the flowers of the other shipping duration treatments post ship. One week postharvest none of the plants had flowers.

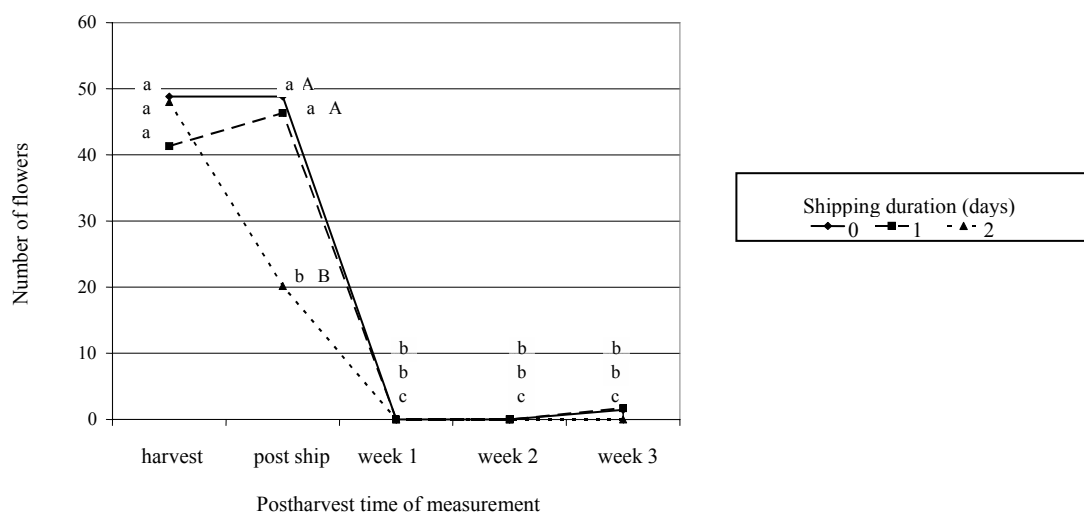


Fig 11. Effect of shipping duration and postharvest time of measurement on number of flowers on *Nemesia × hybrida* 'Aromatica White'. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

Nemesia 'Vanilla Sachet' did not have an effect due to shipping duration on number of flowers. There was a postharvest time of measurement effect on the number of flowers. There were 16.1 flowers at harvest and 20.3 flowers post ship, this change was not significant. One week postharvest the number of flowers on a plant had decreased to 3.6 flowers, two weeks postharvest there were no flowers on the plants.

There was no effect due to nitrogen toning on number of flowers on ‘Aromatica White’ (Table 6). There was an effect due to postharvest time of measurement. At harvest plants had 51.6 flowers. By one week postharvest the number of flowers decreased to 1.8 flowers on the plants. Two weeks postharvest there were no flowers on the plants.

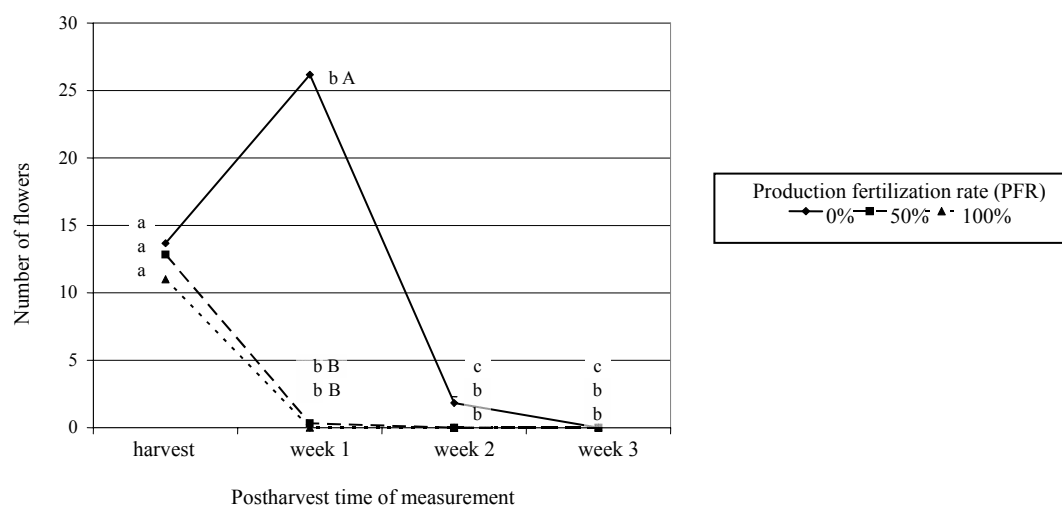


Fig. 12. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on number of flowers on *Nemesia × hybrida* ‘Vanilla Sachet’. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

‘Vanilla Sachet’ had an interaction between nitrogen toning treatments and postharvest time of measurement on number of flowers (Fig. 12). Plants treated with 0%

PFR increased in number of flowers between harvest and one week postharvest. Plants in the other toning treatments had almost no flowers one week postharvest. The number of flowers on the 0% PFR treatment decreased to below five flowers two weeks postharvest. None of the plants had flowers three weeks postharvest.

‘Aromatica White’ did not have an effect due to shipping duration on quality rating (Table 7). The quality decreased at each time of measurement. At harvest quality was 5.00, post ship the plants had a quality of 4.33, one week postharvest the quality was 4.00, two weeks postharvest the quality was 2.00 and three weeks postharvest the quality rating was 1.17. At two weeks postharvest the plants were no longer marketable.

On ‘Vanilla Sachet’ there was an interaction between shipping duration and postharvest time of measurement on quality ratings (Table 31). There was a decrease in quality rating post ship on plants shipped for two days. Other than this difference the plants followed a similar downward trend. Two weeks postharvest there were no differences between the treatments but plants shipped for one day were marketable while plants shipped for zero or two days could not be considered marketable. Three weeks postharvest none of the plants were marketable.

Table 31. Effect of shipping duration and postharvest time of measurement on quality ratings of *Nemesia* × *hybrida* ‘Vanilla Sachet’.

Shipping duration	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
0 days	5.00 A a	5.00 A a	4.17 A b	2.83 A c	0.83 B d
1 day	5.00 A a	5.00 A a	4.33 A b	3.00 A c	2.50 A d
2 days	5.00 A a	3.83 B b	4.50 A c	2.83 A d	1.83 AB e

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

There was an interaction between nitrogen toning and postharvest time of measurement on quality ratings of ‘Aromatica White’ and ‘Vanilla Sachet’ (Tables 9 and 32). ‘Aromatica White’ plants performed similarly until one week postharvest. Plants treated with 50% and 100% PFR were no longer marketable two weeks postharvest whereas plants treated with 0% PFR were marketable. None of the treatments were marketable three weeks postharvest.

Quality ratings of *Nemesia* ‘Vanilla Sachet’ declined two weeks postharvest for all treatments (Table 32). Plants treated with 100% PFR were no longer marketable two weeks postharvest. The plants toned with 50% PFR decreased by a quality rating two weeks postharvest then remained at 3.00 for the rest of the evaluation. The quality rating of plants toned at 0% PFR remained at five until one week postharvest. It had a higher rating than the other treatments until three weeks postharvest. The quality rating decreased two and three weeks postharvest when the plants were still marketable.

Table 32. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on quality ratings of *Nemesia* × *hybrida* cultivars.

Cultivar	Production fertilization rate	Time of postharvest measurement			
		Harvest	One week	Two weeks	Three weeks
Aromatica White	0%	5.00 A a	4.17 A b	3.00 A c	2.00 AB d
	50%	5.00 A a	4.00 A b	1.67 B c	0.83 B d
	100%	5.00 A a	4.00 A b	2.83 A c	2.33 A d
Vanilla Sachet	0%	5.00 A a	5.00 A a	3.50 A b	3.00 A c
	50%	5.00 A a	4.00 B a	3.00 B b	3.00 A b
	100%	5.00 A a	4.00 B a	2.83 B b	1.17 B c

Mean separation within cultivars in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

Two days of shipping caused flower abscission during shipping on ‘Aromatica White’. Nitrogen toning did not affect flower retention of ‘Aromatica White’ but toning with 0% PFR prevented flower abscission on ‘Vanilla Sachet’. There were no effects of shipping on quality of ‘Aromatica White’ while shipping affected the post ship quality of ‘Vanilla Sachet’ plants shipped for two days. Nitrogen toning affected quality of both cultivars. Quality of ‘Aromatica White’ was maintained one week longer on plants treated with 0% PFR. The quality was better on 0% PFR toned plants due to the lack of decline in the vegetative tissues. Nitrogen toning ‘Vanilla Sachet’ with 0% or 50% PFR maintained quality for one week longer than plants that were not toned (100% PFR).

Petunia × *hybrida*

The petunia cultivars grown, ‘Cascadias Pink’ and ‘Suncatcher Pink’, are trailing cultivars with medium sized, medium green leaves and dark pink flowers. ‘Cascadias Pink’ was harvested when it was 22.61 cm tall, had a width index of 30.67 cm and 2.3 flowers. ‘Suncatcher Pink’ was harvested when it was 21.64 cm tall, had a width index of 31.28 cm and 5.3 open flowers. They both displayed lower leaf chlorosis postharvest (Table 3). ‘Suncatcher Pink’ also displayed flower color fading and flower senescence postharvest. The flower color fading was seen on flowers that opened during the evaluation. The flowers appeared lighter in color and were glossier in appearance than the petunia flower was normally.

Petunia ‘Cascadias Pink’ had a difference in width index between nitrogen toning treatments at harvest (Table 4). ‘Suncatcher Pink’ did not have differences due to nitrogen toning at harvest. ‘Cascadias Pink’ plants treated with 100% PFR were wider than those treated with 0% PFR. Plants treated with 50% PFR were intermediate and not different from either treatment.

Petunia ‘Cascadias Pink’ had no effect due to shipping duration on number of flowers (Table 5). There was a main effect due to postharvest time of measurement. The number of flowers increased from 2.3 flowers at harvest to 8.9 flowers one week postharvest. The number then decreased to 6.2 flowers two weeks postharvest and 1.3 flowers three weeks postharvest.

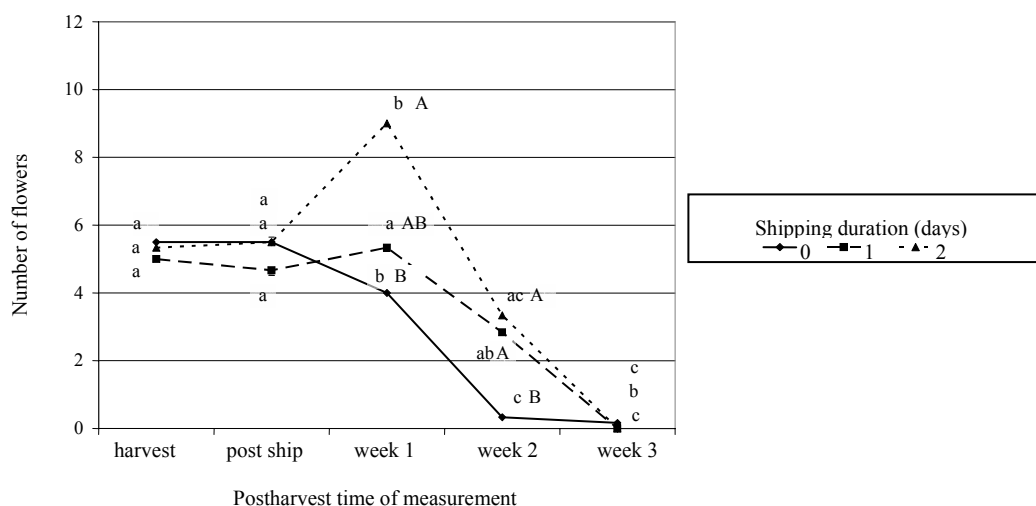


Fig 13. Effect of shipping duration and postharvest time of measurement on number of flowers on *Petunia* \times *hybrida* 'Suncatcher Pink'. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

Petunia 'Suncatcher Pink' had an interaction between shipping duration and postharvest time of measurement on number of flowers (Fig 13). The plants had no differences in number of flowers between shipping durations until one week postharvest. Plants shipped for two days had an increase in number of flowers one week postharvest. The plants shipped for one day did not have a change in number of flowers until three weeks postharvest. There was a decrease in number of flowers for plants shipped zero or two days two weeks postharvest. There was no difference in number of flowers between plants shipped one or two days while plants shipped zero days had fewer flowers two weeks postharvest. By three weeks postharvest none of the treatments had flowers.

‘Cascadias Pink’ and ‘Suncatcher Pink’ had interactions between nitrogen toning and postharvest time of measurement on number of flowers (Table 6). ‘Cascadias Pink’ plants toned with 50% and 100% PFR followed the same declining trend (Fig. 14). The 50% PFR treatment had an increase in number of flowers between harvest and one week postharvest. The number of flowers then decreased to almost no flowers on plants treated with 50% or 100% PFR two weeks postharvest. Plants treated with 0% PFR held flowers through two weeks postharvest. They did not have flowers three weeks postharvest.

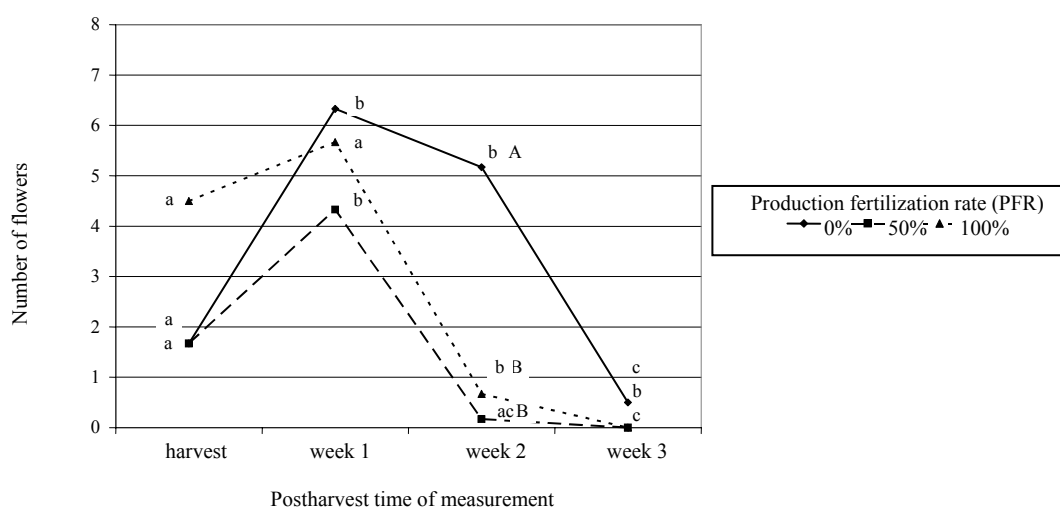


Fig 14. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on number of flowers on *Petunia ×hybrida* ‘Cascadias Pink’. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

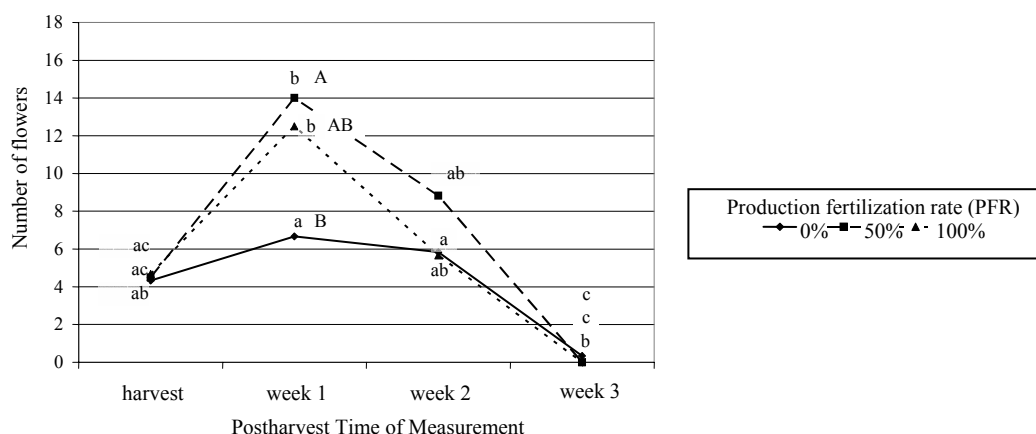


Fig 15. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on number of flowers on *Petunia × hybrida* ‘Suncatcher Pink’. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

‘Suncatcher Pink’ plants treated with 50% or 100% PFR followed a similar trend postharvest (Fig. 15). The number of flowers increased after one week postharvest on plants toned with 50% or 100% PFR while plants toned with 0% PFR maintained their harvest amount. After two weeks postharvest there was no difference in number of flowers between nitrogen toning treatments. Plants toned with 0% PFR did not change in number of flowers until after three weeks postharvest. After three weeks postharvest none of the plants had flowers.

There was no effect of shipping duration on the quality ratings of ‘Cascadias Pink’ (Table 7). There was a postharvest time of measurement effect on quality which remained steady at 5.00 from harvest until one week postharvest. Two weeks

postharvest the quality declined to 3.72 and three weeks postharvest the plants were no longer marketable at a quality rating of 2.72.

Table 33. Effect of shipping duration and postharvest time of measurement on quality ratings of *Petunia* × *hybrida* ‘Suncatcher Pink’.

Shipping duration	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
0 days	5.00 A a	5.00 A a	2.83 B b	2.17 A c	0.67 B d
1 day	5.00 A a	4.00 A b	4.33 A b	2.67 A c	2.33 A c
2 days	5.00 A a	4.00 A b	4.00 A b	2.67 A c	2.17 A d

Mean separation within cultivars in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

There was an interaction between shipping duration and postharvest time of measurement on quality ratings of petunia ‘Suncatcher Pink’ (Table 33). Plants shipped for one or two days followed a similar trend throughout the postharvest evaluation. Plants from these treatments remained marketable until two weeks postharvest. Plants shipped zero days decreased in quality each week after one week postharvest. They were no longer marketable after one week postharvest.

There was an interaction between nitrogen toning and postharvest time of measurement on quality ratings of ‘Cascadias Pink’ (Tables 9 and 34). None of the treatments decreased in quality until two weeks postharvest. Two weeks postharvest,

plants treated with 50% and 100% PFR were no longer marketable. The plants treated with 0% PFR were not marketable three weeks postharvest.

Table 34. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on quality ratings of *Petunia ×hybrida* ‘Cascadias Pink’.

Production fertilization rate	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
0%	5.00 A a	5.00 A a	3.67 A b	2.83 A c
50%	5.00 A a	5.00 A a	2.17 B b	0.33 B c
100%	5.00 A a	5.00 A a	2.67 B b	2.00 A c

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

There was no effect due to nitrogen toning on ‘Suncatcher Pink’ quality ratings. The quality ratings had an effect due to postharvest time of measurement. There was a decline in quality each week from 5.00 at harvest to 4.28 one week postharvest, 3.06 two weeks postharvest and 1.67 three weeks postharvest. Plants were no longer marketable three weeks postharvest.

Shipping duration had no effect on the number of flowers on ‘Cascadias Pink’ while on ‘Suncatcher Pink’ shipped plants retained their flowers longer than unshipped plants. ‘Cascadias Pink’ plants toned with 0% PFR retained their flowers longer than plants toned with 50% or 100% PFR while ‘Suncatcher Pink’ plants toned with 0% PFR had fewer flowers one week postharvest than plants toned with 50% or 100% PFR.

‘Suncatcher Pink’ shipped plants maintained their quality longer than unshipped plants.

The flower retention by ‘Cascadias Pink’ plants toned with 0% PFR may have contributed to the higher quality rating and longer marketability of this treatment.

‘Suncatcher Pink’ did not have any quality ratings effect due to nitrogen toning.

Sutera hybrida and *Sutera cordata*

Sutera hybrida ‘Bridal Showers’ is a low growing plant with small dark green leaves and small, white, flowers made up of four petals. *Sutera cordata* ‘Candy Floss Blue’ had a similar habit but more wirey stems and thinner leaves than ‘Bridal Showers’ with lavender colored flowers. ‘Bridal Showers’ was harvested when it was 13.31 cm tall, with a 25.17 cm width index and had 18.9 flowers. ‘Candy Floss Blue’ was harvested when it was 14.69 cm tall, with a 26.86 cm width index and 45.8 flowers. *Sutera* ‘Bridal Showers’ displayed internode elongation, a decrease in flower size, and flower senescence during the postharvest evaluation (Table 3). ‘Candy Floss Blue’ displayed stem dieback and flower senescence as decline symptoms during the postharvest evaluation.

There was no effect of nitrogen toning on plant height, width index, or number of flowers on either cultivar at harvest (Table 4). There was an interaction between shipping duration and postharvest time of measurement on the number of flowers on *Sutera* ‘Bridal Showers’ (Table 5). There was no change in number of flowers between harvest and post ship on plants shipped zero and one day (Fig. 16). Plants shipped two days had an increase in number of flowers post ship, after this the number of flowers

decreased throughout the postharvest evaluation. One week postharvest plants shipped zero days had no flowers. Two weeks postharvest plants shipped one day had no flowers and three weeks postharvest none of the plants had flowers.

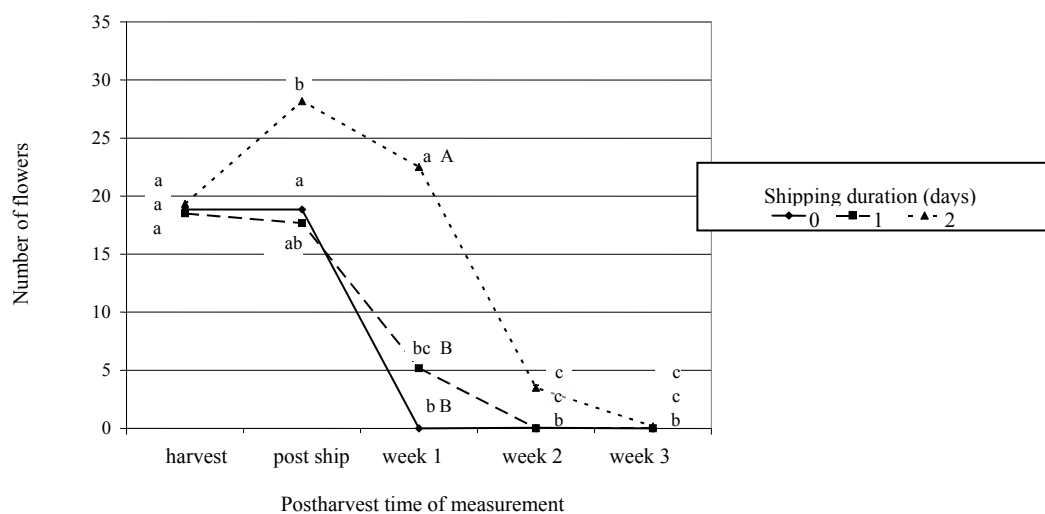


Fig 16. Effect of shipping duration and postharvest time of measurement on number of flowers on *Suteira hybrida* 'Bridal Showers'. Mean separation within treatments (lowercase letters) and between treatments (lowercase letters) by LSD at $P \leq 0.05$.

There were no effects due to shipping duration on number of flowers on 'Candy Floss Blue'. The number of flowers did not significantly change from 45.8 flowers at harvest to 49.8 flowers post ship. One week postharvest there were no flowers on the plants.

There was an interaction between nitrogen toning and postharvest time of measurement on number of flowers on sutera ‘Bridal Showers’ (Table 6). The number of flowers on plants toned with 50% or 100% PFR was the same through the evaluation (Fig. 17). Number of flowers dropped from about 20 flowers to zero flowers one week postharvest. Plants toned with 0% PFR had a decrease in number of flowers one week postharvest (from 25.0 to 16.5). Two weeks postharvest they had zero flowers like the other treatments. Two weeks postharvest they had zero flowers like the other treatments.

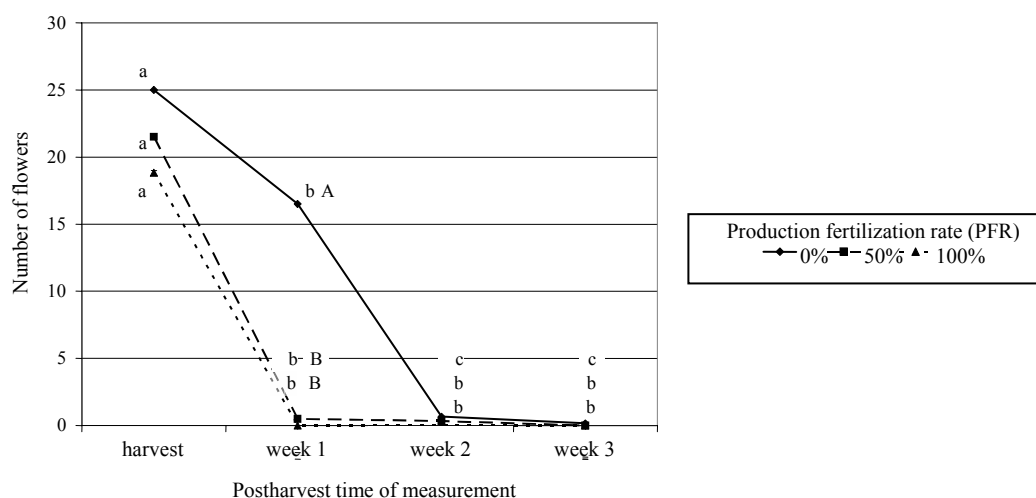


Fig 17. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on number of flowers on *Sutera hybrida* ‘Bridal Showers’. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

Sutera ‘Candy Floss Blue’ had no effect due to nitrogen toning on the number of flowers. The number of flowers declined from 70.1 flowers at harvest to 0.0 flowers one week postharvest. This decline in quality was due to lower leaf chlorosis and necrosis along with internode elongation and flower abscission.

Table 35. Effect of shipping duration and postharvest time of measurement on quality ratings of *Sutera hybrida* ‘Bridal Showers’.

Shipping duration	Time of postharvest measurement				
	Harvest	Post ship	One week	Two weeks	Three weeks
0 days	5.00 A a	5.00 A a	2.83 B b	2.67 B c	2.17 B c
1 day	5.00 A a	4.00 B b	3.00 B c	4.00 A b	3.67 A b
2 days	5.00 A a	4.00 B b	3.83 A b	4.00 A b	4.00 Ab

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

There was an interaction between shipping duration and postharvest time of measurement for quality ratings of ‘Bridal Showers’ (Table 7). The quality rating of ‘Bridal Showers’ declined steadily throughout the postharvest evaluation when shipped zero days (Table 35). Plants shipped one day decreased from harvest until one week postharvest. Quality rating then increased to a rating of four until the end of the postharvest evaluation. Plants shipped for two days remained at a rating of four through most of the postharvest evaluation. These high quality ratings were due to the appearance of the vegetative tissues of the plants. There was no leaf chlorosis, internode

elongation, or other decline symptoms visible except flower abscission. Only the plants shipped for zero days reached an unmarketable stage, this occurred one week postharvest.

There were no effects due to shipping duration on quality ratings of ‘Candy Floss Blue’. There was a postharvest time of measurement effect on quality ratings. The quality ratings declined from 5.00 at harvest to 4.33 post ship. One week postharvest the plants were no longer marketable.

Table 36. Effect of production fertilization rate (nitrogen toning) and postharvest time of measurement on quality ratings of *Sutera hybrida* ‘Bridal Showers’ and *Sutera cordata* ‘Candy Floss Blue’.

Cultivar	Production	Time of postharvest measurement			
	fertilization rate	Harvest	One week	Two weeks	Three weeks
Bridal Showers	0%	5.00 A a	3.33 A c	4.00 A b	4.00 A b
	50%	5.00 A a	3.00 AB c	4.00 A b	2.50 B d
	100%	5.00 A a	2.50 B c	4.00 A b	2.00 B c
Candy Floss Blue	0%	5.00 A a	3.00 A b	3.00 A b	2.83 A b
	50%	5.00 A a	2.50 A b	1.00 B c	0.00 B c
	100%	5.00 A a	3.00 A b	2.17 AB bc	0.50 B c

Mean separation within cultivars in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

A quality of 5=best, <3 = not marketable, 0=death.

There was an interaction between nitrogen toning and postharvest time of measurement on quality ratings of sutera ‘Bridal Showers’ and ‘Candy Floss Blue’ (Table 9). Quality rating of sutera ‘Bridal Showers’ decreased to between 2.50 and 3.33 for all treatments one week postharvest (Table 36). After two weeks postharvest all plants had a quality rating of four due to the lack of decline symptoms on the vegetative tissues. Three weeks postharvest plants toned with 50% or 100% PFR were not marketable while plants toned with 0% PFR were marketable.

There was an interaction between nitrogen toning and postharvest time of measurement on quality rating of sutera ‘Candy Floss Blue’ (Table 36). The quality rating decreased steadily throughout the postharvest evaluation for plants toned with 50% or 100% PFR. One week postharvest plants toned with 50% PFR were not marketable, plants toned with 0% or 100% PFR had a rating of 3.00. Plants toned with 0% PFR remained at three until two weeks postharvest; they were not considered marketable three weeks postharvest.

Sutera ‘Bridal Showers’ and ‘Candy Floss Blue’ reacted differently to shipping duration and nitrogen toning. ‘Bridal Showers’ was affected by shipping duration and nitrogen toning for both number of flowers and quality rating. The only effect due to treatment seen on ‘Candy Floss Blue’ was quality rating of nitrogen toned plants. Shipping for two days and toning with 0% PFR lengthened the amount of time flowers were retained on the ‘Bridal Showers’ plants. Plant shipped for zero days lost their quality faster than those shipped for one or two days. Plants toned with 0% PFR maintained their quality longer than those toned with 50% and 100% PFR. ‘Candy Floss

Blue' plants toned with 0% PFR maintained their quality longer than those toned with 50% or 100% PFR. 'Bridal Showers' maintained its appearance without flowers while 'Candy Floss Blue' vegetative tissues declined in quality along with flower senescence.

Discussion

Postharvest, the species all had different combinations of decline symptoms although the symptoms themselves were shared between several species. Cultivars within a species did not always display the same decline symptoms. Lower leaf chlorosis was the most common decline symptom but several factors could induce this response. The plants were placed close together in a low light postharvest environment. The lack of light reaching the lower leaves could have induced chlorosis. The cessation of fertilizer and movement of mobile nutrients such as nitrogen, potassium, and phosphorus to new tissue by the plant also could have encouraged leaf chlorosis. Internode elongation occurred on about half the species. This elongation may have been induced by the reduced light intensity in the simulated interior environment or the red: far-red light quality in the simulated interior environment. In the postharvest growth room (simulated retail environment) the lights used were metal halide bulbs. Metal halide lamps have little activity in the red light range (650 to 700 nm) but there is a spike of light in the far-red range (700 to 750 nm) of the spectrum (Nelson, 2003). Senescence followed chlorosis; these plants were no longer visually pleasing and would not have been marketable after leaf senescence occurred. Overall they did not display these

Table 37. Postharvest longevity and effects of shipping duration and nitrogen toning on the quality ratings on 21 cultivars of vegetative annuals.

Species	Cultivar	Postharvest		
		longevity (weeks)	Shipping effect	Nitrogen toning effect
<i>Angelonia angustifolia</i>	Caritas Lavender	1	No	No
<i>Argyranthemum frutescens</i>	Comet White	3	No	Yes
<i>Argyranthemum frutescens</i>	Sunlight	3	Yes	No
<i>Bracteantha bracteata</i>	Dreamtime Copper	3	No	Yes
<i>Bracteantha bracteata</i>	Dreamtime Cream	3	No	Yes
<i>Bracteantha bracteata</i>	Florabella Gold	3	Yes	Yes
<i>Bracteantha bracteata</i>	Florabella White	3	No	No
<i>Bracteantha bracteata</i>	Sundaze Bronze	1	Yes	No
<i>Bracteantha bracteata</i>	Sundaze Golden Yellow	1	No	No
<i>Calibrachoa</i> hybrid	Liricashowers Deep Blue Imp.	2	Yes	No
<i>Calibrachoa</i> hybrid	Starlette Trailing Purple	3	No	Yes
<i>Calibrachoa</i> hybrid	Superbells Trailing Blue	2	No	No
<i>Diascia</i> × <i>hybrida</i>	Sunchimes Coral	2	Yes	Yes
<i>Lantana camara</i>	Lucky Lemon Cream	2	Yes	No
<i>Lantana camara</i>	Lucky Peach Sunrise	3+	No	No
<i>Nemesia</i> × <i>hybrida</i>	Aromatica White	2	No	Yes
<i>Nemesia</i> × <i>hybrida</i>	Vanilla Sachet	2	Yes	Yes
<i>Petunia</i> × <i>hybrida</i>	Cascadias Pink	3	No	Yes
<i>Petunia</i> × <i>hybrida</i>	Suncatcher Pink	2	Yes	No
<i>Sutera hybrida</i>	Bridal Showers	3+	Yes	Yes
<i>Sutera cordata</i>	Candy Floss Blue	1	No	Yes

postharvest decline symptoms until they had been in the growth room for one week.

A summary of plant responses to shipping duration and nitrogen toning are in Table 37. Overall two cultivars had a shelf life of greater than three weeks, eight cultivars had a shelf life of three weeks, seven cultivars had a shelf life of one week and four cultivars had a shelf life of two weeks.

Overall, shipping was not detrimental however shipping caused flower abscission on diascia ‘Sunchimes Coral’ and nemesia ‘Aromatica White’. Opening of new flowers during shipping is a possible explanation for the significant decrease in flower number after one day of shipping but no difference between the zero and two days of shipping treatments for diascia ‘Sunchimes Coral’. Nemesia ‘Aromatica White’ appeared to have lost flowers during two days of simulated shipping and did not open new flowers. Both diascia and nemesia are members of Scrophulariaceae. Plants from that family, i.e. *Antirrhinum majus* L. and *Veronica spicata* L. are ethylene sensitive (Woltering and Van Doorn, 1988). They found flower abscission to be the response of Scrophulariaceae when exposed to ethylene.

Shipping affected the quality of 43% of the cultivars. However, only three cultivars had decreased quality of calibrachoa ‘Liricashowers Deep Blue Imp.’, diascia ‘Sunchimes Coral’, and lantana ‘Lucky Lemon Cream’ on plants shipped for two days. All other cultivars were not negatively affected by shipping duration.

In the shipping experiment, during the postharvest evaluation calibrachoa ‘Superbells Trailing Blue’ and nemesia ‘Aromatica White’ were the only cultivars to abscise flowers after the first week. By two weeks postharvest seven of the 21 cultivars

had abscised all flowers. After two weeks postharvest 11 of the 21 cultivars did not have a high enough quality rating (3.0) to be considered marketable. Two weeks is the amount of time Nell and Hoyer (1995) stated as the minimum amount of time a flowering plant should live in an interior environment. The plants we studied were outdoor bedding plants not interior flowering potted plants. These results indicate plants held inside a shop instead of an outdoor area need to be sold within the first week to have the consumer receive a high quality plant. According to Nelson, the postharvest environment should have low light and temperature, exposure to ethylene should be avoided and irrigation should occur at the onset of stress to prolong shelf life (1998).

Nitrogen toning had beneficial effects on postharvest longevity of nine cultivars. Beneficial effects included decreased plant width which aids in shipping, reduction in flower abscission or increase in flower opening or increase in quality by reducing decline symptoms and prolonging marketability. Nitrogen toning affected bracteantha at harvest. Either height or width index was different on all bracteantha cultivars except 'Sundaze Golden Yellow'. During the postharvest evaluation, the lantana cultivars and calibrachoa 'Superbells Trailing Blue' showed no plant growth responses due to toning. All other species showed differences in flower number and/or quality rating postharvest. Of the nine cultivars that had toning and postharvest time of measurement interactions plants from five cultivars toned with 0% PFR had higher quality ratings than plants from the other toning rates. Two other cultivars had higher quality on plants toned with 0% or 50% PFR than those toned with 100% PFR. Of the cultivars not affected by nitrogen

toning only three (bracteantha 'Florabella White', lantana 'Lucky Peach Sunrise', and petunia 'Suncatcher Pink') were marketable after two weeks postharvest.

In general, the number of flowers decreased after one week of postharvest evaluation. The quality decreased to unmarketable after two weeks of postharvest evaluation. Plant quality and number of flowers postharvest was found to decrease with increased concentration of fertilizer on *Begonia* \times *semperflorens-cultorum* Hort. (Conover et al., 1993). This same study found quality and number of flowers increased as lighting increased. This environmental factor probably contributed to the rate of decline postharvest in our study. The light level in the growth room (six to 10 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) was set to equal the light level in an interior room lit with fluorescent lights which is lower than ideal for a bedding plant. Light levels of 50 to 150 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (250 to 750 fc) are cited as ideal for bedding plants postharvest by Nelson (1998).

The postharvest evaluation in both experiments indicated time had a more pronounced effect on number of flowers and quality than nitrogen toning or shipping duration. There were few significant differences unless an interaction with time occurred.

In all but nemesia and sutera there were differences in postharvest longevity between cultivars (Table 37). In all but bracteantha, one cultivar lasted one week longer than the other cultivars of that species. The bracteantha Dreamtime series cultivars reacted similarly while 'Florabella White' lasted longer than 'Florabella Gold' and 'Sundaze Golden Yellow' lasted longer than 'Sundaze Bronze'.

From these experiments, diascia and bracteantha were chosen for future study. Shipping duration and temperature as well as plant growth regulator (1-methylcyclopropene) effects on postharvest life of diascia were studied because of their tendency to drop flowers during shipping. Nitrogen toning and the effect of a plant growth regulator (thidiazuron) on growth response and postharvest life of bracteantha were studied due to this species response to nitrogen.

CHAPTER III

SHIPPING TEMPERATURE AND 1-MCP EFFECT ON POSTHARVEST LIFE OF *DIASCIA XHYBRIDA*

Introduction

Diascia ×hybrida (diascia) is a South African native species in the Scrophulariaceae. It is a relatively new vegetative annual on the floriculture market and is becoming increasingly popular. It comes in a variety of flower colors mostly in the pink and peach palette such as the cultivars grown in these experiments, but also includes red, lavender and white. They grow to about 30 cm tall with an upright or trailing habit and need full sun. ‘Wink Lavender Pink’ was an upright, trailing cultivar and ‘Sunchimes Coral’ was trailing. The leaves of diascia are creanate to serrate and one to three cm in length. The flowers have twin spurs in back and are attached by a filamentous peduncle to the raceme. Each flower is about 2 cm in diameter with a fused corolla.

After treating 26 flowering plant species and 26 foliage plant species with 0 to 15 $\mu\text{L}\cdot\text{L}^{-1}$ ethylene for 24 or 72 hours at 20 °C in the dark, Woltering (1985) found ethylene toxicity symptoms included leaf chlorosis and abscission, flower and bud blasting and abscission, epinasty, fruit ripening and abscission, and microbial attack. Plants in Scrophulariaceae displayed an intermediate to very high sensitivity to ethylene and had hastened flower senescence in the presence of ethylene (Woltering and Van Doorn,

1988). Upon exposure to a 0.3 Pa ethylene environment at 20 °C, 60% RH, and 12 hours of $15 \text{ mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, *Antirrhinum majus* L. displayed between 33% and 66% flower abscission and *Chelone barbatus* Cav. (*Penstemon barbatus*, Beardtongue) and *Veronica orchidea* Crantz. displayed between 66% and 99% flower abscission within 24 hours of exposure. *Veronica longifolia* L. and *Veronica spicata* L. had an immediate dramatic response when exposed to ethylene.

Serek, et al. (1995) found continuous exposure to $1 \text{ }\mu\text{L}\cdot\text{L}^{-1}$ exogenous ethylene reduced vase life of cut *A. majus* but treatment with 1-methylcyclopropene (1-MCP) for six hours prolonged vase life by more than one day. 1-Methylcyclopropene is an ethylene inhibitor and may become a replacement for silver thiosulfate. Silver thiosulfate (STS) has been used as a spray or vase solution in industry as an ethylene inhibitor on cut and pot flower crops such as *Euphorbia pulcherrima* Willd., *Matthiola incana* L., and *Schlumbergera truncata* (Haw.) Moran (Veen, 1983). However there are environmental concerns in using a heavy metal and the disposal thereof. No differences in display life were seen between plant growth regulator treatments when *Begonia × elatior hybrida* Fotsch., *Rosa hybrida* L., or *Kalanchoe blossfeldiana* Poelln. were pretreated with $5 \text{ nL}\cdot\text{L}^{-1}$ of 1-MCP or 0.5 mM STS and then placed in a 0 or $5 \text{ }\mu\text{L}\cdot\text{L}^{-1}$ ethylene environment (Serek et al, 1994).

During shipping, ethylene can build up while the plants are enclosed in boxes and/or a truck. Research has been conducted on many fruit, vegetable, and flowering species investigating the ability of 1-MCP to reduce ethylene effects during storage and shipping. It was found to delay ripening in *Carica papaya* L. (papaya) when treated

with $25 \mu\text{L}\cdot\text{L}^{-1}$ for 14 hours at 20°C . It also was found to delay senescence in *Coriandrum sativum* L. (coriander) when treated with $50 \text{ nL}\cdot\text{L}^{-1}$ for 24 hours at 20°C (Blankenship and Dole, 2003). When cut racemes of blue, white and pink flowering *Lupinus harvardii* Wats. were treated for 12-16 hours with 1-MCP, treated racemes had reduced flower senescence and abscission in the presence of exogenous ethylene (2-chloroethylphosphonic acid at 10-500 μmol in the vase solution) (Sankhla et al., 2001).

We are not aware of any research on the effectiveness of 1-MCP on flowers at different stages of development. In bananas (*Musa paradisiaca* L.), Harris et al. (2000) found a difference in the effectiveness of 1-MCP due to the maturity of the bananas treated. Less mature bananas treated with $500 \text{ nL}\cdot\text{L}^{-1}$ 1-MCP ripened faster than those not treated with 1-MCP. Mature bananas had delayed ripening when treated with the same amount of 1-MCP. Bananas treated with 5 or $50 \text{ nL}\cdot\text{L}^{-1}$ 1-MCP did not show differences in ripening due to maturity.

There has been no research on diascia in relationship to shipping and ethylene. In our earlier experiments, it was noted diascia leaves appeared water-soaked and flower senescence and abscission occurred after two days of simulated shipping. The objective of our research was to determine the postharvest response of diascia to various shipping temperatures and durations and to investigate the effects of 1-MCP on these responses.

Materials and Methods

COMMON PROCEDURE. Rooted 27 mL rooted liners (three strips of 34 rooted liners/tray) of diascia ‘Wink Lavender Pink’ from Simply Beautiful (Ball FloraPlant, Chicago, IL)

were received on 9 Sept. 2003 for experiment six and 7 Jan. 2004 for experiment seven. Rooted 20 mL rooted liners (105 rooted liners/tray) of 'Sunchimes Coral' were received from Flower Fields (Paul Ecke Ranch, Encinitas, CA) on 7 Jan. 2004. Three hundred plants were planted for experiment six and one hundred plants of each cultivar were planted for experiment seven. They were planted in soil-less media (ProMix BX, Premier Brands, Quakertown, PA) in 11.4 cm (415 mL) geranium pots (Dillon Products, Middlefield, OH) on 17 Sept. for experiment six and on 13 Jan. for experiment seven. They were grown in a glass greenhouse with temperature set points of 24° /18 °C day/ night for experiment six (Appendix Fig. A-3). Experiment seven had temperature set points of 18°/16 °C day/ night temperature set points until 27 Jan. when the night temperature was lowered to 13°C (Appendix Fig. A-4). They were kept pot tight on the bench until 1 Oct. for experiment six and until 4 Feb. for experiment seven when they were spaced to 1 plant/ 230 cm².

The plants in experiment six were fertilized at each irrigation with 20N-3.4P-16.6K (Peter's Professional, Scotts-Sierra Horticultural Products Company, Marysville, OH) at 300 mg·L⁻¹ until 8 Oct. then 15N-5.4P-14.1K (Peter's Professional, Scotts-Sierra Horticultural Products Company, Marysville, OH) at 300 mg·L⁻¹ until harvest. Experiment seven plants received 15N-5.4P-14.1K at 300 mg·L⁻¹ until harvest. Plants were watered by hand and reverse osmosis (RO) water was used at all irrigations due to unsuitable tap water. Due to the use of RO water, a Soluble Trace Element Mixture (STEM, Peter's Professional, Scotts-Sierra Horticultural Products Company, Marysville, OH) drench was applied at 30 mg·L⁻¹ on 8 Oct. (Expt. 6) and 27 Jan. (Expt. 7).

A broad spectrum fungicide {Etridiazole (5-Ethoxy-3-trichloromethyl-1,2,4-thiadiazole) and Thiophanate {thiophanate-methyl[Dimethyl(1,2-phenylene) bis (iminocarbonothioyl)] bis (carbamate)}; Banrot 40%WP, Scotts-Sierra Crop Protection Company, Marysville, OH} was applied at $59.8 \text{ mg}\cdot\text{L}^{-1}$ to prevent root rot diseases on 19 Sept. and 24 Oct. (expt.6) and 20 Jan (expt. 7). Imidacloprid {1-[(6-Chloro-3-pyridinyl)methyl]-*N*-nitro-2-imidazolidinimine; Marathon 1% Granular; Olympic Horticultural Products, Mainland, PA} was applied on 2 Oct. at 1.4 g/pot for systemic insect control. A paclobutrazol {B-[(4-chlorophenyl)methyl]- α -(1,1-dimethyl)-1*H*-1,2,4-triazole-1-ethanol}; Bonzi; Uniroyal Chemical, Middlebury, Conn.} drench was applied on 9 Oct. at $0.5 \text{ mL}\cdot\text{L}^{-1}$ for height control. Experiment seven plants were not treated with imidacloprid or paclobutrazol because these chemicals were not needed when plants were grown at the cooler temperature.

The plants were considered marketable when there was a minimum of six racemes on a plant had at least one open flower. A flower was considered open when pollen was visible on the anther. At harvest but before treatment, data measured included plant width index, plant height, number of open flowers, and number of racemes with open flowers. Plant height was measured from the base of the pot to the highest point on the plant. Plant width index was the average of two plant width measurements taken perpendicularly across the plant canopy.

The 1-MCP (1-Methylcyclopropene, Ethylbloc, Floralife, Waterboro, SC) treatments were conducted according to manufacturer's directions. Plants were packed in a shipping box (7 plants/ box with empty 11.4 cm geranium pots between the plants

for spacing) which was placed on their corresponding cart (control or 1-MCP). The cart was covered with a 4-mil clear polyethylene tarp and sealed to the concrete floor with duct tape. The 1-MCP treatment was applied at 0.2 g powder / 5 ml buffer solution as a gas for four hours. The 1-MCP was added using plastic bottles with pop-tops. Just prior to sealing the plastic tarp to the ground, the bottle was placed under the plastic and the top was opened to release the gas. The tarp was completely sealed after the bottles were positioned. The control plants were treated similarly except the pop-top bottle contained only RO water.

Plants were not watered during simulated shipping. They were watered when removed from the boxes and while in the growth chamber as needed from a watering can with RO water.

When removed from the boxes and weekly thereafter, open flower number and the number of racemes with open flowers were counted, and each plant was given a quality rating (Table 38, Fig. 18). Two weeks after treatment the experiment was terminated. Measurements were taken at four times for experiment six and five times for experiment seven, hereafter termed postharvest time of measurement. These postharvest times of measurement included at harvest, post ship, after one week postharvest, and after two weeks postharvest. In addition, for experiment seven, postharvest time of measurement included after three weeks postharvest. At harvest was at removal from the greenhouse and immediately prior to shipping. Post ship was immediately upon removal from box and prior to placing in the simulated interior i.e. growth room. One week postharvest was one week after the two days of simulated shipping treatment.

Harvest data was analyzed using ANOVA and Least Squared Difference (LSD) test by the SAS program (SAS 8.01; SAS Institute, Cary, NC). Repeated measure analysis of number of flowers and flowering racemes was conducted as a split plot design using the Proc Mixed procedure in SAS with LSD for mean separation. Quality ratings were analyzed as repeated measure categorical data using the Proc Genmod procedure in SAS with Chi-squared for means separation.

Table 38. Postharvest quality rating for *Diascia* \times *hybrida*.

Quality rating	Postharvest quality
5	Plant is healthy – no visible decline symptoms
4	<25% flowers abscised and/ or visible fading in flower color and/ or <25% of lower leaves chlorotic
3	100% flowers abscised or >25% flowers abscised and/or >25% lower leaves chlorotic and/ or <10% lower leaves senesced
2	>10% lower leaves senesced and 100% flowers abscised and/ or <25% dead stems
1	>25% dead stems, 100% flowers abscised, and/or 100% lower leaves senesced
0	Total plant senescence



Quality Rating 5

Quality Rating 4



Quality Rating 3

Quality Rating 2



Quality Rating 1

Fig. 18. Top view of postharvest quality ratings of *Diascia* \times *hybrida* 'Wink Lavender Pink'.

EXPERIMENT 6 – EFFECTS OF 1-MCP AND SHIPPING DURATION ON POST-HARVEST PERFORMANCE OF DIASCIA ‘WINK LAVENDER PINK’. The simulated shipping (SS) experiment was conducted three times: SS-1 was 31 Oct., SS-2 was 5 Nov., and SS-3 was 7 Nov. Each harvest consisted of forty-two plants selected for uniformity and then divided into six treatments of seven plants per treatment. Treatments were factorial with 3 shipping durations of 0, 1, or 2 days and a 1-MCP treatment or water (control). After four hours, the plants were moved to a growth room set at 20 °C (actual 18.7 ± 0.6 °C) and $10 \pm 4 \mu\text{mol/m}^2/\text{s}$. Because there were no available growth chambers to simulate shipping Fall 2003; to simulate shipping in this experiment, the boxes remained closed and stacked in the growth room. The plants were removed from the boxes immediately (0 ship days), after 24 hours (1 ship day), or after 48 hours (2 ship days) after treatment. They were spaced on benches in the growth room and monitored for their postharvest responses.

EXPERIMENT 7 – EFFECTS OF 1-MCP AND SHIPPING TEMPERATURE ON POSTHARVEST PERFORMANCE OF *DIASCIA XHYBRIDA* CULTIVARS. Each cultivar was harvested at three times as plants reached harvest maturity. ‘Sunchimes Coral’ was harvested on 1, 3, and 5 Mar. while ‘Wink Lavender Pink’ was harvested on 8, 10, and 15 Mar. Each harvest was a different simulated shipping temperature. The experiment was factorial with three shipping temperatures 13, 18, and 24 °C (Appendix Fig. A-7), and two plant growth regulator treatments (control or 1-MCP). The plants were shipped for two days and there were seven plants per treatment. Separate groups of plants were also treated with 1-MCP or control and placed directly into the growth room without shipping.

Once gassed, the unshipped plants were moved to a growth room set at 20 °C (actual 15.4 ± 3.6 °C) (Appendix Fig. A-10) and $10 \pm 4 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ and the shipped plants went into a growth chamber set at 50% RH and $0 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. The temperature of the growth chamber was set according to the treatment. The plants were removed from the boxes immediately for the unshipped treatments or after 48 hours of simulated shipping in the growth chamber. Three weeks after treatment the experiment was terminated.

Results

EXPERIMENT 6 – EFFECT OF SHIPPING DURATION AND 1-MCP ON POST-HARVEST PERFORMANCE OF DIASCIA ‘WINK LAVENDER PINK’. Twice as many plants as needed for the experiment were grown to assure availability of uniform plants at the maturity needed. Height, width index, number of flowers and racemes were measured to verify

Table 39. Plant height, width index, number of flowers and racemes with open flowers of all plants at harvest for three simulated shipments (SS) of *Diascia* \times *hybrida* ‘Wink Lavender Pink’.

Simulated shipments	Plant height (cm)	Plant width index (cm)	Flower number	Raceme number
SS-1	21.38 ± 2.15	28.82 ± 2.72	34.3 ± 11.8	11.8 ± 3.8
SS-2	20.27 ± 1.73	31.23 ± 4.17	72.1 ± 33.5	21.0 ± 8.4
SS-3	21.75 ± 2.57	32.57 ± 5.33	87.6 ± 36.9	24.8 ± 8.5

Mean of 42 plants \pm SE.

uniformity between shipping durations within simulated shipments (Table 39). Plants for the first shipment were selected from those that matured first. Plants for subsequent shipments matured later but by harvest, although similar in height and width had developed more flowers.

There were three factors that had three way interactions: the SS-1 flower number, SS-1 raceme number, and SS-3 quality (Table 40). The three way interactions will not be discussed further.

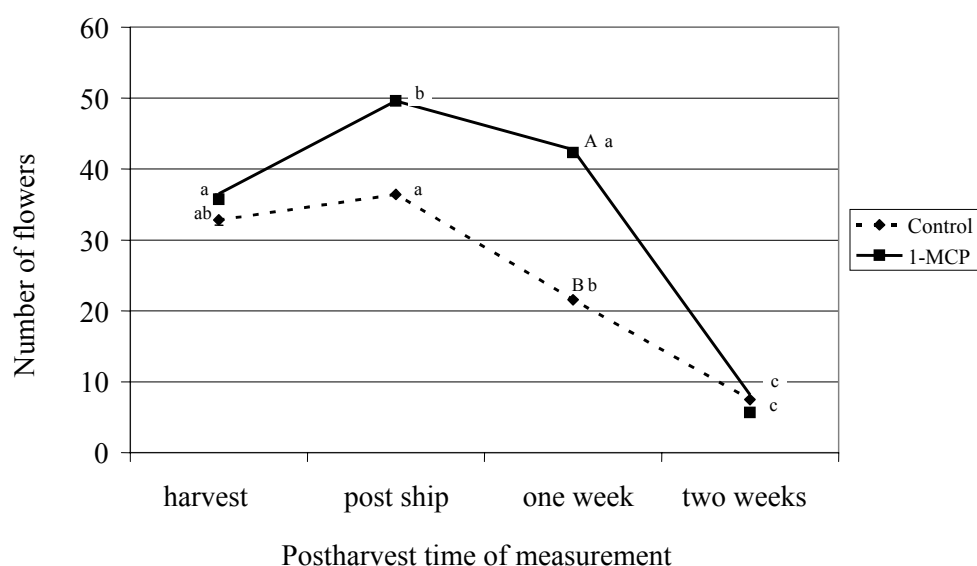


Fig 19. Effect of 1-MCP and postharvest time of measurement on number of flowers during the first simulated shipping (SS-1) of *Diascia ×hybrida* ‘Wink Lavender Pink’. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

Table 40. Repeated measure F-test for effect of 1-methylcyclopropene (1-MCP), shipping duration, and postharvest time of measurement on number of flowers and racemes and quality rating of *Diacia × hybrida* ‘Wink Lavender Pink’.

	Simulated shippings								
	SS-1			SS-2			SS-3		
	Flower	Raceme	Quality	Flower	Raceme	Quality	Flower	Raceme	Quality
	(no.)	(no.)	rating	(no.)	(no.)	rating	(no.)	(no.)	rating
1-MCP	*	NS	NS	NS	NS	NS	NS	NS	NS
Shipping duration	NS	NS	NS	NS	NS	NS	NS	NS	NS
Postharvest time of measurement	***	***	***	***	***	***	***	***	***
1-MCP × shipping duration	NS	NS	NS	NS	NS	NS	NS	NS	NS
1-MCP × postharvest time of measurement	***	*	NS	*	**	NS	NS	NS	NS
Shipping duration × postharvest time of measurement	*	*	***	**	**	NS	NS	NS	NS
1-MCP × shipping duration × postharvest time of measurement	*	*	NS	NS	NS	NS	NS	NS	**

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

In SS-1, number of flowers and number of racemes had two-way interactions for 1-MCP treatment and postharvest time of measurement. They also had two way interactions for shipping duration and postharvest time of measurement. The 1-MCP treatment had increased number of flowers post ship (Fig. 19). One and two weeks postharvest the number of flowers decreased. The control treatment had a decreased

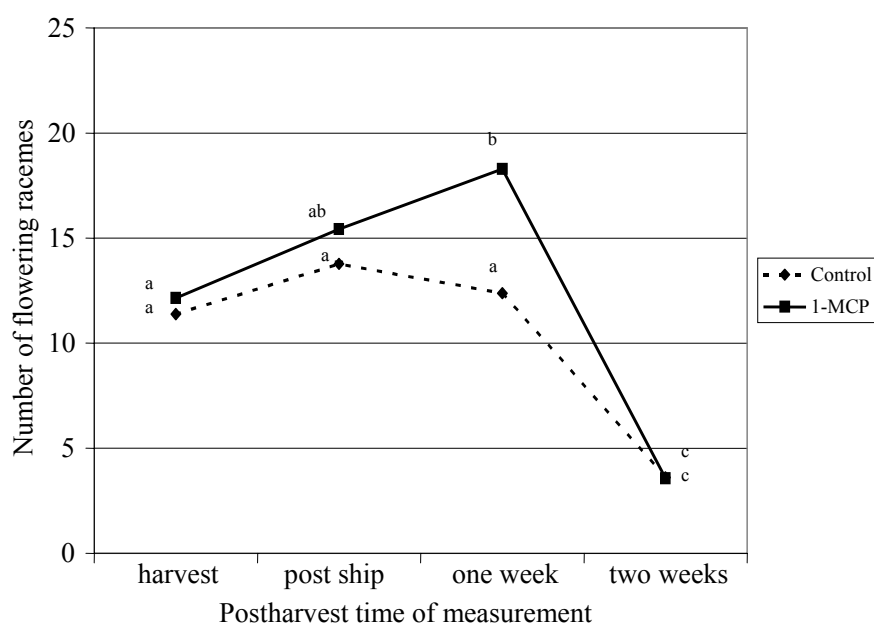


Fig 20. Effect of 1-MCP and postharvest time of measurement on number of flowering racemes during the first simulated shipping (SS-1) of *Diascia ×hybrida* ‘Wink Lavender Pink’. Mean separation within treatments (lowercase letters) by LSD at $P \leq 0.05$. There were no differences between treatments at each time of measurement.

number of flowers between post ship and one week postharvest. The 1-MCP treated plants had more flowers than the control plants one week postharvest. Two weeks postharvest both treatments had less than half the flowers they had at harvest.

For number of flowering racemes there was an interaction between 1-MCP and postharvest time of measurement (Fig. 20). Both treatments had 11.8 flowering racemes at harvest. The number of flowering racemes on the control plants did not change until after two weeks postharvest. The 1-MCP treated plants had increased number of flowering racemes after one week postharvest. Both treatments decreased to <5 flowering racemes after two weeks postharvest which was a loss of 50% from the number of racemes at harvest.

The interaction of shipping duration and postharvest time of measurement on number of flowers occurred due to the two days of simulated shipping treatment (Fig 21). There were no differences between treatments at harvest or post ship. After post ship, the two day shipping duration had reduced number of flowers and fewer flowers than plants shipped for one day. The number of flowers on plants shipped for two days continued to decline. The zero and one day shipping treatments declined in number of flowers one week postharvest. By two weeks postharvest there were no differences between the three treatments. Plants of all treatments went from 30 to 40 flowers at harvest to approximately ten or less after two weeks postharvest.

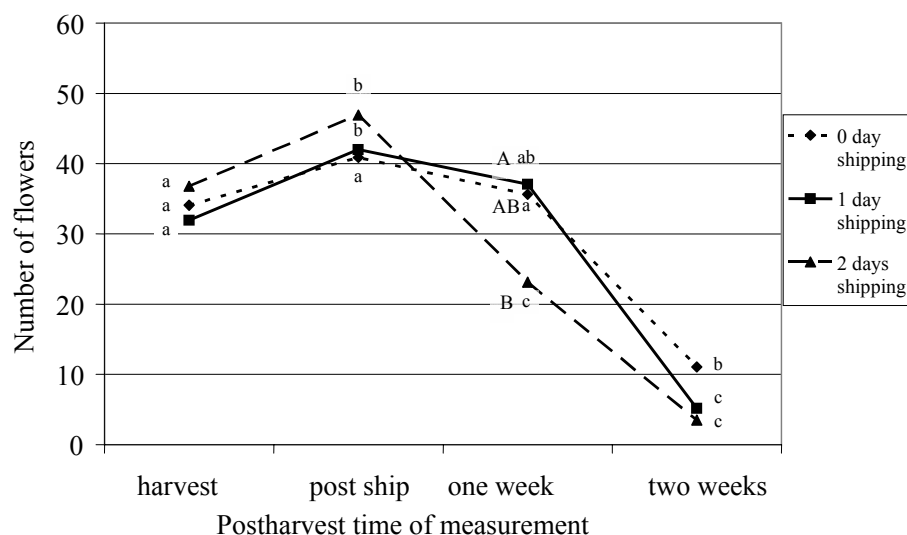


Fig 21. Effect of shipping duration and postharvest time of measurement on number of flowers during the first simulated shipping (SS-1) of *Diascia × hybrida* 'Wink Lavender Pink'. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

The interaction of shipping duration and postharvest time of measurement on the number of flowering racemes occurred due to the two days of simulated shipping treatment (Fig. 22). The number of flowering racemes did not decrease during the simulated shipping. There was an increase in flowering racemes between harvest and after one week postharvest for the zero day and one day shipping treatments. After one week postharvest, plants shipped two days had less flowering racemes than the post ship level. After two weeks postharvest all treatments had decreased numbers of flowering racemes.

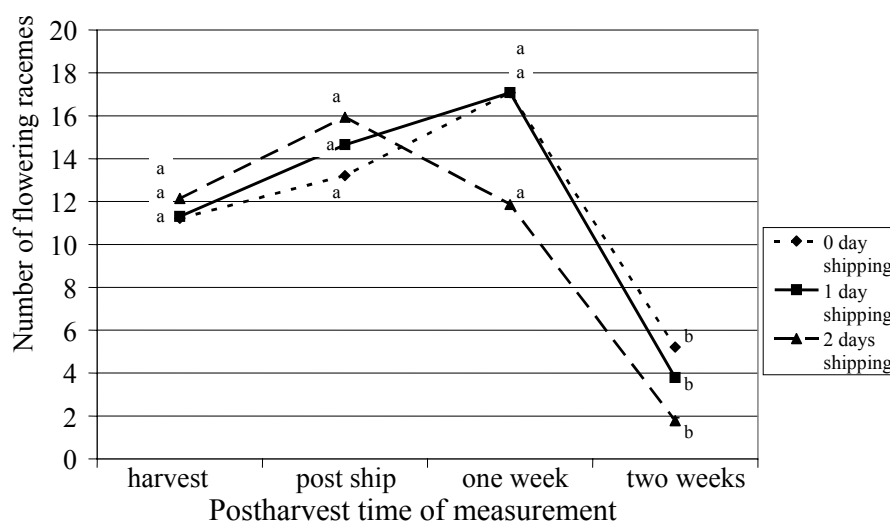


Fig 22. Effect of shipping duration and postharvest time of measurement on number of flowering racemes during the first simulated shipping (SS-1) on *Diascia* \times *hybrida* 'Wink Lavender Pink'. Mean separation within treatments (lowercase letters) by LSD at $P \leq 0.05$. There were no differences between treatments at each time of measurement.

In SS-1 there was no effect of 1-MCP on quality. There was an interaction between shipping duration and postharvest time of measurement for quality of SS-1 *diascia* plants. There was no difference between the treatments at harvest (Table 41). Plants shipped for two days had decreased number of flowers post ship. After one week postharvest there was a decrease in quality for all treatments. At this time there was a significant difference between the two days of shipping treatment and the other treatments. After one week postharvest, the plants that were not shipped and those shipped one day averaged above a quality rating of 3.00. These treatments would still be

considered marketable. The two days of shipping treatment had a quality less than 3.00 and would not be marketable. Two weeks after shipping none of the treatments were different or considered marketable. This loss in quality was due to flower abscission, lower leaf chlorosis and senescence.

Table 41. Effect of shipping duration and postharvest time of measurement on quality rating during the first simulated shipping (SS-1) on *Diascia ×hybrida* ‘Wink Lavender Pink’.

Shipping duration	Harvest	Post ship	Week 1	Week 2
0 days	5.00 A a	5.00 A a	3.29 A b	1.21 A c
1 day	5.00 A a	4.93 AB a	3.21 A b	1.43 A c
2 days	5.00 A a	4.71 B b	2.21 B c	1.14 A d

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

By the time of the second shipment, five days after the first shipment, plants had 72.1 flowers on 21.0 racemes. The second simulated shipping (SS-2) had two-way interactions for 1-MCP treatment and postharvest time of measurement and shipping duration and postharvest time of measurement for number of flowers and flowering racemes (Table 40). Quality was not affected by shipping or 1-MCP treatment.

The number of flowers did not change until after two weeks postharvest for the 1-MCP treated plants (Fig 23). The control plants had a decrease in number of flowers

after one week postharvest. The 1-MCP plants retained their flowers until two weeks postharvest. There was a difference between treatments post ship and one week postharvest. Plants treated with 1-MCP had more flowers than the control plants at both times of measurement. Both treatments had the same number of flowers after two weeks postharvest which had declined to about ten flowers.

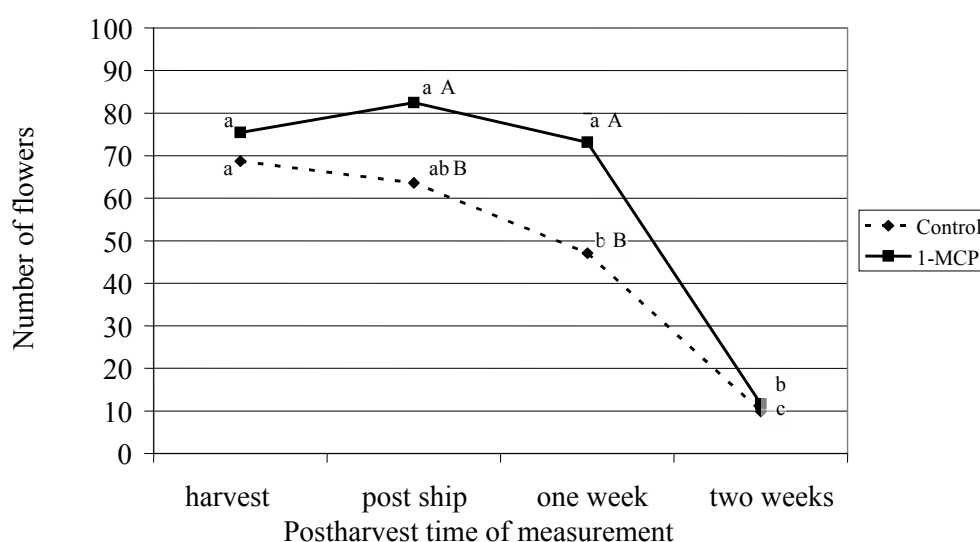


Fig 23. Effect of 1-MCP and postharvest time of measurement on number of flowers during the second simulated shipping (SS-2) on *Diascia ×hybrida* 'Wink Lavender Pink'. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

The number of flowering racemes for the second shipment decreased after two weeks postharvest for both the 1-MCP and the control treatment (Fig. 24). There was an increase in flowering racemes for the 1-MCP treatment after one week postharvest and

1-MCP treated plants had more flowering racemes than the controls due to continued opening of flowers on these plants. Two weeks after harvest both treatments only had about 50% of the racemes they had at harvest.

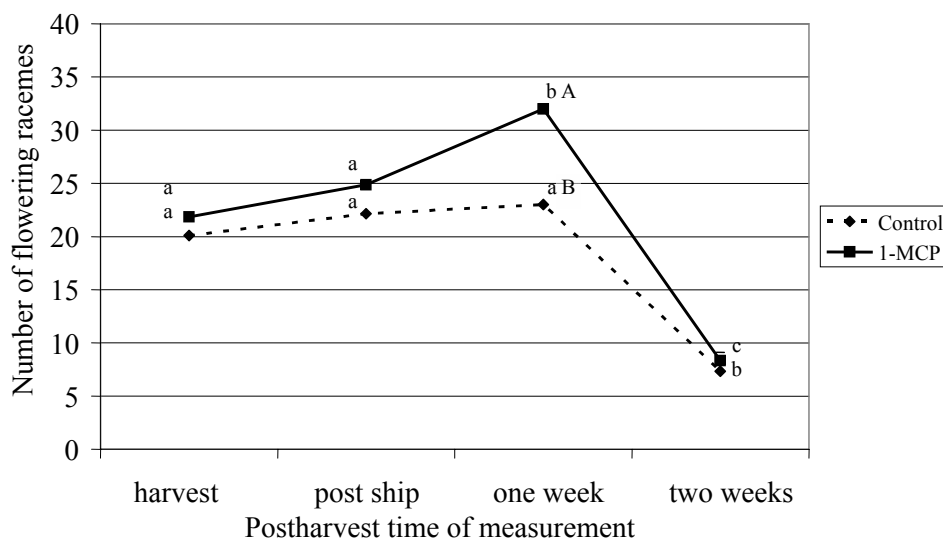


Fig. 24. Effect of 1-MCP and postharvest time of measurement on number of flowering racemes during the second simulated shipping (SS-2) on *Diascia ×hybrida* ‘Wink Lavender Pink’. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

There was an effect of shipping duration and postharvest time of measurement on number of flowers in the second simulated shipping (SS-2). The control and one day of shipping treatments did not change in number of flowers until two weeks postharvest (Fig. 25). For the two days of shipping treatment, number of flowers decreased one

week postharvest and again two weeks postharvest. All plants decreased to the same number of flowers after two weeks postharvest.

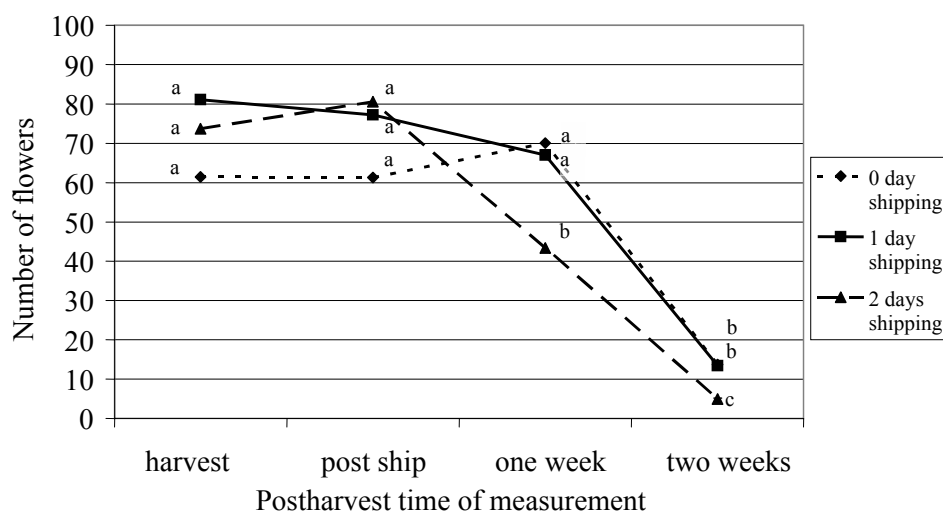


Fig 25. Effect of shipping duration and postharvest time of measurement on number of flowers during the second simulated shipping (SS-2) on *Diascia ×hybrida* ‘Wink Lavender Pink’. Mean separation within treatments (lowercase letters) by LSD at $P \leq 0.05$. There were no differences between treatments at each time of measurement.

There were no differences in the number of flowering racemes between shipping treatments at any postharvest time of measurement (Fig. 26). Plants shipped for zero days had an increase in number of flowering racemes one week postharvest. The number of flowering racemes on plants shipped did not change until two weeks

postharvest. All treatments had a decrease in the number of flowers after two weeks postharvest.

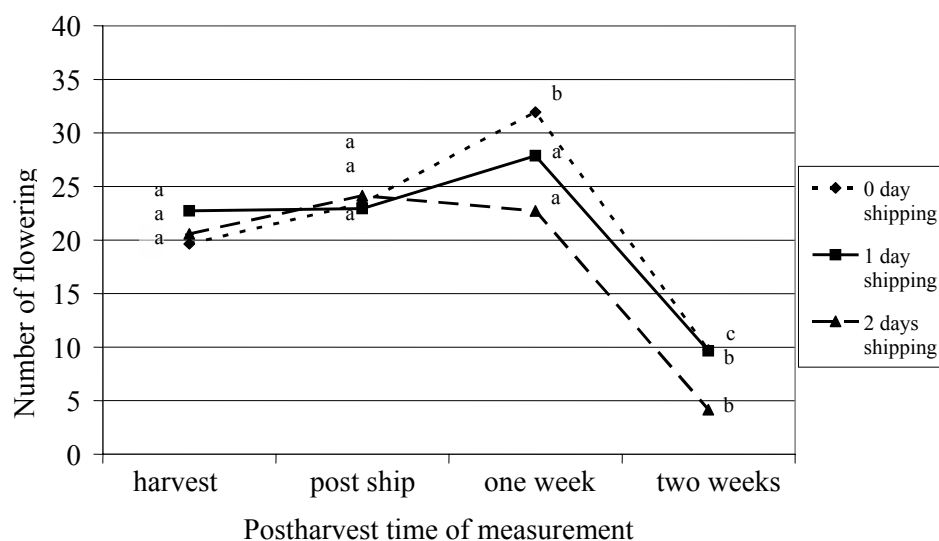


Fig 26. Effect of shipping duration and postharvest time of measurement on number of flowering racemes during the second simulated shipping (SS-2) on *Diascia* × *hybrida* 'Wink Lavender Pink'. Mean separation within treatments (lowercase letters) by LSD at $P \leq 0.05$. There were no differences between treatments at each time of measurement.

The main effect of postharvest time of measurement was significant for quality on SS-2. In general, the quality was 5.00 at harvest and post ship but decreased to 3.50 after one week and 2.00 after two weeks regardless of 1-MCP or shipping treatment.

The third simulated shipping (SS-3) had a significant three way interaction for quality. No other variables were different due to 1-MCP or shipping duration.

Table 42. Effect of postharvest time of measurement on number of flowers, racemes and quality ratings during the third simulated shipping (SS-3) on *Diascia* × *hybrida* ‘Wink Lavender Pink’.

	Harvest	Post ship	One week	Two weeks
Number of flowers ^z	87.5 a	74.7 b	36.6 c	1.7 d
Number of racemes ^z	24.8 a	25.1 a	19.9 b	1.3 c
Quality rating ^{yx}	5.00 a	5.00 a	3.33 b	1.36 c

^z Means separation in rows by LSD at $P \leq 0.05$.

^y Mean separation in rows by χ^2 at $P \leq 0.05$.

^x Quality of 5=best, <3 = not marketable, 0=death.

Postharvest time of measurement was significant for number of flowers, racemes and quality rating (Table 42). The number of flowers decreased at each postharvest time of measurement. The number of flowering racemes decreased after one and two weeks postharvest. The plants had less than two flowers and racemes after two weeks postharvest. Quality ratings decreased one and two weeks postharvest. Plants were no longer marketable two weeks postharvest.

EXPERIMENT 7 – EFFECTS OF 1-MCP AND SHIPPING TEMPERATURE ON POSTHARVEST PERFORMANCE OF *DIASCIA XHYBRIDA* CULTIVARS. At harvest and prior to shipping temperature treatment there were no significant differences between the treatments for each cultivar for any of the variables (Table 43).

Table 43. Plant height, width index, number of flowers and racemes measured at harvest and prior to shipping temperature treatment for *Diascia* \times *hybrida* ‘Sunchimes Coral’ and ‘Wink Lavender Pink’.

Diascia cultivar	Plant height	Plant width index	Flower number	Raceme number
Sunchimes Coral	24.67 \pm 3.20	28.64 \pm 13.65	40.1 \pm 10.1	8.9 \pm 2.3
Wink Lavender Pink	23.09 \pm 1.64	29.17 \pm 3.00	26.7 \pm 9.3	8.7 \pm 2.6

Mean of 84 plants \pm SE.

Table 44. Repeated measure F-test for effect of 1-methylcyclopropene (1-MCP), simulated shipping temperature and postharvest time on number of flowers, racemes and quality rating of shipped *Diascia* \times *hybrida* ‘Wink Lavender Pink’.

	Flower (no.)	Raceme (no.)	Quality ratings
1-MCP	NS	NS	NS
Temperature	NS	*	NS
Postharvest time of measurement	***	***	***
1-MCP \times temperature	NS	NS	NS
Temperature \times postharvest time of measurement	NS	NS	***
1-MCP \times postharvest time of measurement	NS	NS	NS
1-MCP \times temperature \times postharvest time of measurement	NS	NS	*

NS, *, *** Nonsignificant or significant at $P \leq 0.05$, 0.001, respectively.

The shipped ‘Wink Lavender Pink’ had a significant three way interaction for quality rating (Table 44). There were no other significant three way interactions for either ‘Sunchimes Coral’ or ‘Wink Lavender Pink’. ‘Sunchimes Coral’ had an interaction between shipping temperature and postharvest time of measurement for all three measured variables (Table 45). 1-MCP did not affect the measured variables. ‘Wink Lavender Pink’ had an interaction for quality rating between shipping temperature and postharvest time of measurement. The main effect of shipping temperature for flowering racemes was significant.

Table 45. Repeated measure F-test for effect of 1-MCP, simulated shipping temperature and postharvest time of measurement on number of flowers, racemes and quality rating of shipped *Diascia × hybrida* ‘Sunchimes Coral’.

	Flower (no.)	Raceme (no.)	Quality ratings
1-MCP	NS	NS	NS
Temperature	**	**	NS
Postharvest time of measurement	***	***	***
1-MCP × temperature	NS	NS	NS
Temperature × postharvest time of measurement	***	***	***
1-MCP × temperature	NS	NS	NS
1-MCP × temperature × postharvest time of measurement	NS	NS	NS

NS, **, *** Nonsignificant or significant at $P \leq 0.01$, 0.001, respectively.

Table 46. Repeated measure F-test for effect of 1-methylcyclopropene (1-MCP) and postharvest time of measurement on number of flowers, racemes and quality rating of unshipped *Diascia × hybrida* ‘Sunchimes Coral’.

	Flower (no.)	Raceme (no.)	Quality rating
1-MCP	NS	NS	NS
Postharvest time of measurement	***	***	***
1-MCP × postharvest time of measurement	**	*	NS

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

Table 47. Repeated measure F-test for effect of 1-methylcyclopropene (1-MCP) and postharvest time of measurement on number of flowers, racemes and quality rating of unshipped *Diascia × hybrida* ‘Wink Lavender Pink’.

	Flower (no.)	Raceme (no.)	Quality ratings
1-MCP	*	*	NS
Postharvest time of measurement	***	***	***
1-MCP × postharvest time of measurement	NS	*	NS

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

The unshipped plants had a 1-MCP effect and postharvest time of measurement interaction for number of flowers and flowering racemes in ‘Sunchimes Coral’ (Table

46). There was a postharvest time of measurement for quality rating of ‘Sunchimes Coral’. ‘Wink Lavender Pink’ had an interaction between 1-MCP and postharvest time of measurement on number of flowering racemes (Table 47). The main effect of 1-MCP was significant for number of flowers for ‘Wink Lavender Pink’ and postharvest time of measurement was significant for number of flowers and quality on ‘Wink Lavender Pink’.

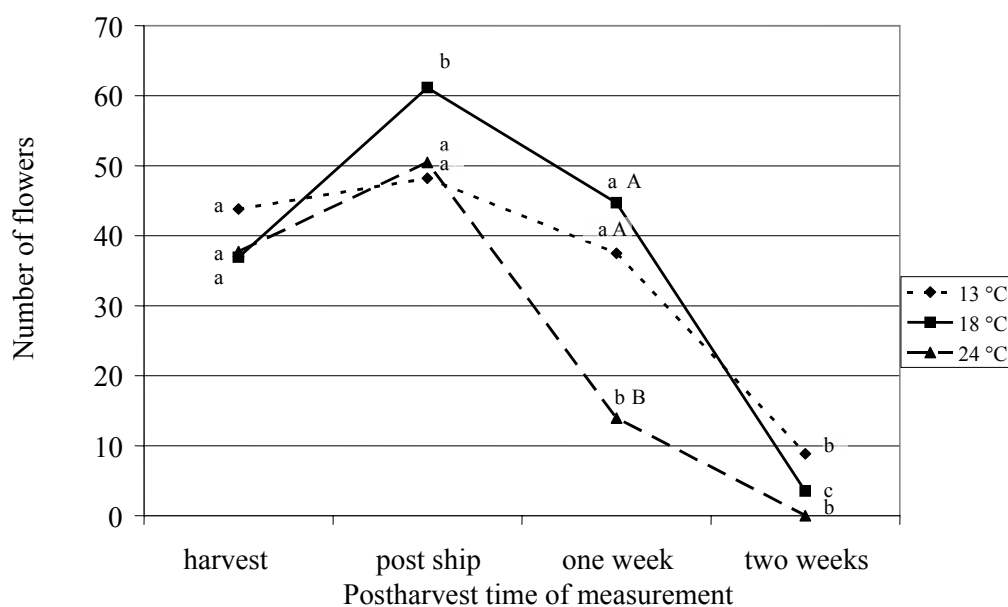


Fig 27. Effect of shipping temperature and postharvest time of measurement on number of flowers on *Diascia x hybrida* ‘Sunchimes Coral’. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

The number of flowers did not change after shipping at 13 and 24 °C for ‘Sunchimes Coral’ (Fig. 27). The 18 °C treatment increased in number of flowers post ship. After one week postharvest the number of flowers decreased on plants shipped at 18 and 24 °C, plants shipped at 13 °C had no change in number of flowers until two weeks postharvest. Plants in the 24 °C treatment had fewer flowers than the 13 or 18 °C treatments at one week. After two weeks postharvest all treatments significantly decreased to the same amount of flowers.

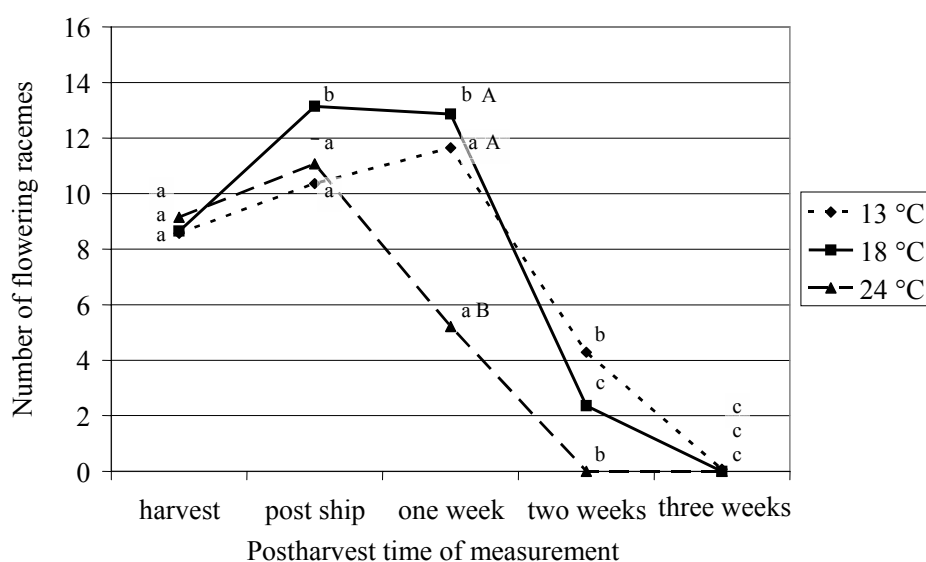


Fig 28. Effect of shipping temperature and postharvest time of measurement on flowering racemes of *Diascia ×hybrida* ‘Sunchimes Coral’. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

The number of flowering racemes on plants shipped at 18 °C increased during shipping and they decreased two weeks postharvest (Fig 28). The number of flowering racemes did not change for the 13 °C treatment until two weeks postharvest. The 24 °C treatment decreased in flowering racemes one week postharvest. At one week postharvest the 24 °C had fewer flowering racemes than the other shipping treatments. After two weeks all treatments had the same number of flowering racemes. After three weeks, all racemes had abscised.

‘Wink Lavender Pink’ had a main effect of postharvest time of measurement for number of flowers and flowering racemes (Table 48). The number of flowers decreased one week postharvest and by two weeks postharvest plants had less than one flower per plant.

Table 48. Effect of postharvest time of measurement on number of flowers and racemes on shipped *Diascia ×hybrida* ‘Wink Lavender Pink’.

	Harvest	Post ship	One week	Two weeks	Three weeks
Number of flowers	26.4 a	28.1 a	2.0 b	0.9 b	0.1 b
Number of racemes	8.6 b	10.4 a	0.8 c	0.5 c	0.1 c

Means separation in rows by LSD at $P \leq 0.05$

‘Wink Lavender Pink’ had an increase in flowering racemes post ship (Table 48). One week postharvest the number of flowering racemes had dropped to less than one per plant. There was also a main effect of shipping temperature on the number of flowering

racemes on ‘Wink Lavender Pink’. The plants shipped at 13 °C more flowering racemes (4.9 racemes) than plants shipped at 18 °C (3.8 racemes) and 24 °C (3.4 racemes).

Table 49. Effect of shipping temperature and postharvest time of measurement on quality rating of *Diascia ×hybrida* ‘Sunchimes Coral’.

Shipping temperature					
(°C)	Harvest	Post ship	One week	Two weeks	Three weeks
13	5.00 A a	5.00 A a	3.86 A b	2.64 A c	1.71 A d
18	5.00 A a	5.00 A a	3.71 AB b	2.71 A c	1.36 A d
24	5.00 A a	5.00 A a	2.92 B b	1.57 B c	1.43 A c

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

The quality of ‘Sunchimes Coral’ had a significant decrease in all shipping temperature treatments after one and two weeks postharvest (Table 49). There were no significant differences between the 13 and 18 °C treatments through the evaluation. One week postharvest, the 13 and 18 °C treatments were still above a quality rating of 3.00 while the 24 °C treatment was not marketable. The quality of plants shipped at 24 °C was less than the other treatments one and two weeks after shipping. All plants had poor quality rating of <2 after three weeks postharvest. The low quality rating was due to flower and raceme abscission along with lower leaf chlorosis and senescence.

Table 50. Effect of shipping temperature and postharvest time of measurement on quality rating of *Diascia ×hybrida* ‘Wink Lavender Pink’.

Shipping temperature					
(°C)	Harvest	Post ship	One week	Two weeks	Three weeks
13	5.00 A a	5.00 A a	1.29 A b	1.14 AB b	0.71 A c
18	5.00 A a	5.00 A a	1.50 A b	0.79 B c	0.71 A c
24	5.00 A a	3.93 B b	1.50 A c	1.14 A d	0.57 A e

Mean separation in rows (lowercase letters) and columns (uppercase letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

The quality of ‘Wink Lavender Pink’ plants had an interaction between shipping temperature and postharvest time of measurement. The 24 °C treatment decreased in quality during simulated shipping and was different from the other temperature treatments post ship (Table 50). After one week postharvest all three treatments significantly decreased in quality. They were not marketable at this time. After two weeks postharvest the 18 °C treatment was lower in quality than the 24 °C treatment, three weeks postharvest there were no differences in quality between treatments.

The unshipped ‘Sunchimes Coral’ had an interaction between 1-MCP treatment and postharvest time of measurement for number of flowers (Fig. 29) due to control plants losing flowers faster than the 1-MCP plants. There was a decrease in flower number of both treatments after one and two weeks postharvest. After three weeks postharvest both treatments had 100% flower abscission. At no time of measurement did the treatments differ in number of flowers.

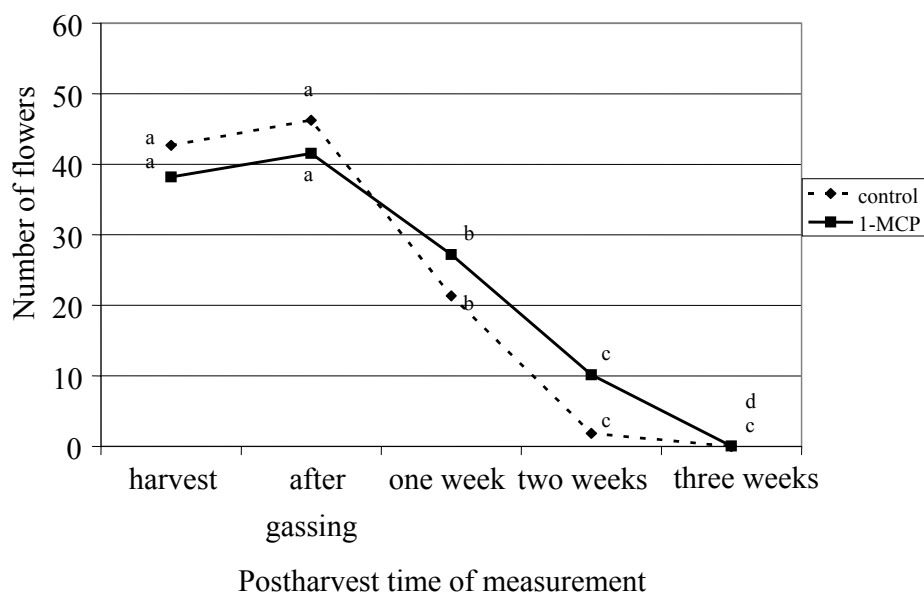


Fig. 29. Effect of 1-MCP and postharvest time of measurement on number of flowers postharvest on unshipped *Diascia × hybrida* ‘Sunchimes Coral’. Mean separation within treatments (lowercase letters) by LSD at $P \leq 0.05$. There were no differences between treatments at each time of measurement.

‘Wink Lavender Pink’ had main effects of 1-MCP and postharvest time of measurement on flower number. The 1-MCP treatment had 13.4 flowers while the control had 10.8 flowers. For postharvest time of measurement effects, the number of flowers was not different from harvest to post ship, they decreased from 28.2 flowers post ship to 3.8 flowers one week postharvest, they then decreased to 1.1 flowers after two weeks and 0.5 flowers three weeks postharvest.

There was an interaction between 1-MCP treatments and postharvest time of measurement for number of flowering racemes of unshipped ‘Sunchimes Coral’ plants

(Fig. 30). Two weeks postharvest both treatments significantly decreased and were different from one another. The 1-MCP treatment had more flowering racemes longer than the control. Three weeks postharvest there were no flowering racemes on either treatment.

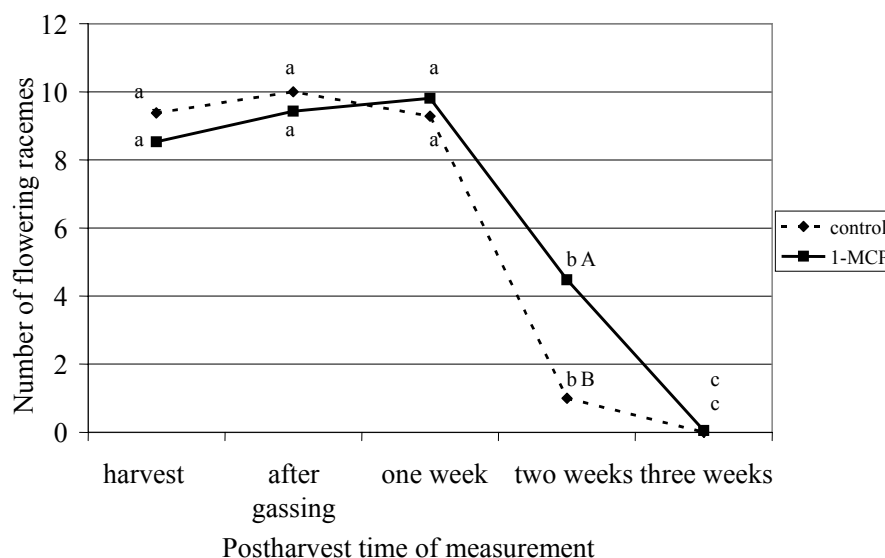


Fig. 30. Effect of 1-MCP and postharvest time of measurement on flowering racemes of unshipped *Diascia ×hybrida* ‘Sunchimes Coral’. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

The unshipped ‘Wink Lavender Pink’ had an interaction between 1-MCP and postharvest time of measurement for the number of flowering racemes. The number of flowering racemes decreased significantly for both treatments after one week postharvest

(Fig 31). The 1-MCP treatment had more flowering racemes than the control one week postharvest. At this point the control had no flowering racemes while the 1-MCP treatment had three flowering racemes. The number of flowering racemes decreased on the 1-MCP treatment between one and three weeks postharvest.

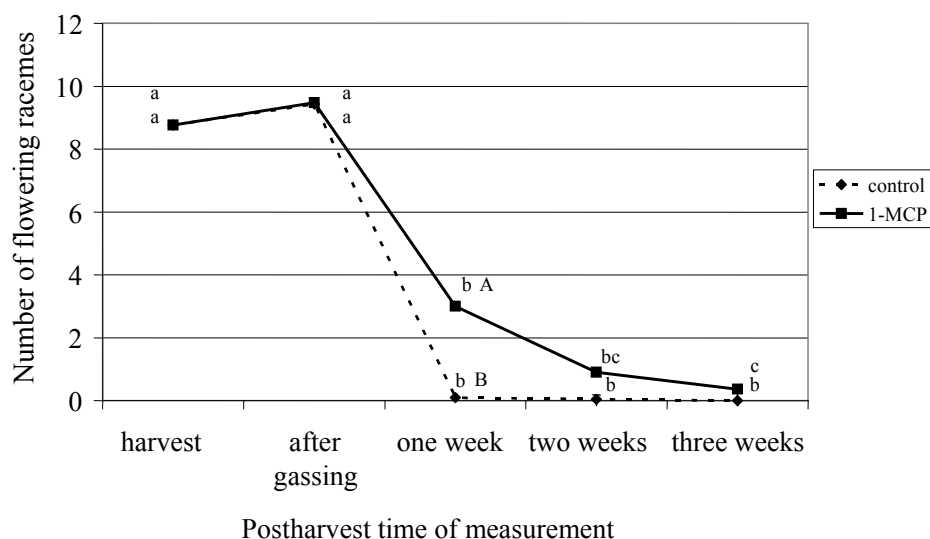


Fig 31. Effect of 1-MCP and postharvest time of measurement on flowering racemes of unshipped *Diascia ×hybrida* 'Wink Lavender Pink'. Mean separation within treatments (lowercase letters) and between treatments (uppercase letters) by LSD at $P \leq 0.05$.

There was a main effect of postharvest time of measurement on quality rating of 'Sunchimes Coral'. The quality rating was not different from harvest to post ship. It decreased from 5.00 to 3.64 one week postharvest, it then decreased to 2.43 two weeks

and 1.52 three weeks postharvest. The plants were no longer marketable two weeks postharvest.

There was no effect due to 1-MCP on the quality of unshipped 'Wink Lavender Pink'. There was an effect due to postharvest time of measurement. The quality decreased from 5.00 at harvest and post ship to 1.45 one week postharvest. This decline placed the quality below our standard of marketability. The quality continued to decline through the rest of the evaluation.

Discussion

In both experiments the decrease in number of flowers was related to a decrease in number of flowering racemes. Often there was a lag between the decrease in number of flowers and the decrease in number of flowering racemes. In order for a flowering raceme to be counted it only needed one open flower. At the beginning of the experiments plants would have multiple flowers on a raceme. As the experiments progressed the number of flowers on a raceme decreased while the number of flowering racemes would remain relatively steady for a period of time.

For two shipping times in experiment 6, plants shipped for two days had a greater loss of flowers and flowering racemes after one week postharvest compared to plants shipped for zero or one day. This increased flower loss could be due to ethylene exposure while in shipping or a response to prolonged darkness while in simulated shipping. Flower drop in the presence of ethylene was seen on *Veronica longifolia* L. (Woltering and Van Doorn, 1988). *V. longifolia* (Scrophulariaceae) had an immediate

dramatic response when exposed to 0.3 Pa ethylene for 22-24 h. Quality of the diascia declined more with two days of shipping in the first simulated shipment. This was not seen in the other simulated shipments. Plants in all treatments still had flowers after one week postharvest. The quality decrease in plants shipped for two days was related to lower leaf chlorosis and senescence. The loss of flowers and other decline symptoms caused plants shipped for two days to be unmarketable after one week, while those shipped zero or one day were marketable one additional week.

Plants treated with 1-MCP retained flowers and opened new flowers during shipment and after one week postharvest. The plant shelf life improvement in the presence of 1-MCP indicates ethylene has a role in determining the shelf life of diascia. Diascia 'Wink Lavender Pink' had a postharvest longevity of one week. This shelf life is not considered acceptable by the definition put forth by Nell and Hoyer (1995). They asserted a flowering potted plant should last two weeks postharvest. Light levels may have impacted the postharvest performance. Diascia is a full sun bedding plant but was held in low light levels during the postharvest evaluation.

In experiment seven, the shipping temperature impacted all three postharvest variables on 'Sunchimes Coral'. Plants shipped at 18 °C increased in number of flowers post ship while the other temperature treatments had no change from the number of flowers at harvest. By one week postharvest the number of flowers on plants from the 24 °C treatment had decreased while the other treatments declined at a similar rate.

Quality was affected by shipping temperature for both diascia cultivars. When plants were shipped at 24 °C they declined in quality faster than those shipped at a

cooler temperature. 'Wink Lavender Pink' was not marketable one week postharvest while 'Sunchimes Coral' plants shipped at 13 or 18 °C were marketable until two weeks postharvest. This is of concern in a warmer climate if the plants remain in the shipping conditions for longer than a day. Shipping at a cooler temperature appears to help maintain flowers and quality on a plant postharvest.

There was a 1-MCP effect on number of flowers on shipped 'Sunchimes Coral' but not on 'Wink Lavender Pink'. The treated plants held their flowers longer than the untreated plants. 'Sunchimes Coral' had 40 flowers at harvest while 'Wink Lavender Pink' plants only had 26 flowers. This difference in number of flowers may have affected the amount of ethylene produced by the plants during shipping and this in turn may have affected the amount of flowers lost. On the unshipped plants, 1-MCP improved plant quality and held flowers longer during the postharvest evaluation.

Whether 1-MCP is beneficial to postharvest shelf life is unclear from these experiments. Experiment six had positive flower retention with 1-MCP but in experiment seven there was no difference between treated and control plants that were shipped. In experiment seven shipping temperature and time had a greater effect on variables measured than 1-MCP. When plants were not shipped 1-MCP improved flower retention by seemingly preventing flower abscission on both 'Sunchimes Coral' and 'Wink Lavender Pink'.

From these experiments it can be concluded diascia lasts longer when shipped for one day or less at temperatures below 24 °C. The effects of 1-methylcyclopropene may be improved by increasing exposure time to the gas or increasing the concentration

applied to the plants, further studies are needed. The effect of 1-MCP is only seen shortly after application. These diascia cultivars lost most of their flowers during their first week in the postharvest environment. Studies into prolonging the effect of 1-MCP through re-application or use in combination with other plant growth regulators would be helpful. Studies using other diascia cultivars may be useful to obtain an idea of how the species as a whole reacts to these treatments.

CHAPTER IV

THE EFFECT OF NITROGEN TONING AND THIDIAZURON ON *BRACTEANTHA BRACTEATA*

Introduction

Bracteantha bracteata (Vent.) Anderb. & Haegi is an Australian native species in the Asteraceae. Commonly it is known as bracteantha, strawflower, everlasting flower, or paper daisy. It is grown as a cut flower and as a landscape plant and we are investigating growing it as a potted plant.

Most research conducted on bracteantha has been in the realm of cut flowers and their production. Photoperiod, temperature and plant age were studied by Sharman et al. (1989). They found long day photoperiod reduced time to flowering. They also found the number of inflorescence reaching anthesis was increased by long days but the total number of inflorescences was greater on those grown under short day photoperiod. Time to anthesis was reduced in bracteantha with increased temperature from 15 to 25 °C. Plant height and diameter were reduced with increasing temperature. Basappa et al. (1990) studied the effect of nitrogen and phosphorus on *Bracteantha* cut flower yield in a field grown situation. They tested nitrogen and phosphorus levels of 0, 50, 100, and 150 kg/ha. Plants had the highest flower yield at the highest nitrogen level (150 kg/ha) while with phosphorus the greatest yield was achieved at 100 kg/ha. A combination of these

levels of nutrients produced the greatest flower yield of 9.24 tonnes/ha. Both these studies were conducted on seed grown bracteantha plants.

Thidiazuron (TDZ) has cytokinin-like properties (Pavlista et al, 2003) and creates an accumulation or synthesis of purine cytokinins (Thomas and Katterman, 1986). It was found to reduce leaf chlorosis on cut *Alstromeria pelegrina* L. when used as a 24 h. pulse treatment at 10 μ M. They found leaves on treated stems were held for more than 60 days and the chlorophyll content of the leaves increased for three weeks after treatment. The chlorophyll content of the control leaves decreased after six days of vase life (Ferrante et al, 2001). Cut *Tulipa gesneriana* L. (tulips) and *Dendranthema \times grandiflorum* Kitam. (chrysanthemum) were pulsed with vase solutions of 10, 50, and 100 μ M TDZ for 24 h. It was found TDZ treated cut flowers had reduced stem elongation, delayed leaf chlorosis and the total chlorophyll content of the leaves was increased. Leaf chlorosis of the control occurred after seven to nine days of vase life while the TDZ treated leaves remained green for more than 20 days. TDZ treatment also prolonged the vase life of cut 'Regan Bianco' chrysanthemums. Leaves of treated cut flowers had a 44% increase in chlorophyll content from the harvest measurement to the end of vase life. Axillary shoot formation was induced by TDZ treatment (Ferrante et al., 2003).

Nitrogen toning has been found to increase postharvest shelf life and reduce bud and leaf drop on some plant species. Termination of fertilizer (300 mg·L⁻¹ N) three weeks before harvest (total of 11 weeks of production to harvest) was found to increase pot chrysanthemum longevity postharvest but not flower diameter or time to open

flowers (Nell et al., 1989). *Impatiens hawkeri* Bull. (New Guinea impatiens) were found to have a 15% reduction in bud and leaf abscission when fertilized with 100 mg·L⁻¹ N as compared to those fertilized with 150 mg·L⁻¹ N from potting until harvest (ter Hell and Hendriks, 1995). They also found pot roses fertilized with 200 mg·L⁻¹ N from potting until one month before harvest had 30% more bud and leaf abscission than those fertilized with 100 mg·L⁻¹ N during the same time period.

In our earlier experiments nitrogen toning, i.e. reducing production rate fertilization from 300 to 0 mg·L⁻¹ two weeks before harvest, reduced plant height and/or width of five of six cultivars of bracteantha. It was noted bracteantha of the Sundaze series produced a disproportionately large number of leaves for their given pot size. Disease became a problem due to reduced air flow when the plants were grown at an economical spacing (43.1 plants/m²). Lower leaf chlorosis was also seen during the early experiments. The objectives of these experiments were to determine if nitrogen toning and TDZ could increase shelf life, control lower leaf chlorosis, and reduce the amount of vegetative growth of bracteantha cultivars.

Materials and Methods

PROCEDURE COMMON TO ALL EXPERIMENTS. Rooted 20 mL (105 rooted liners/ tray) rooted liners of *Bracteantha bracteata* Sundaze series were received from Proven Winners (EuroAmerican Propagators, Bonsall, CA). Sundaze 'Bronze', 'Golden Beauty', 'Golden Yellow', 'Pink', and 'White' were grown for experiments four and five. 'Bronze', 'Pink', and 'White' were grown for experiment eight. The rooted liners

were planted on 5 June 2003 for experiments four and five and on 26 Feb. 2004 for experiment eight. They were planted in soil-less media (ProMix BX, Premier Brands, Quakertown, PA) in 12.7 cm (535 mL) azalea pots (Dillon Products, Middlefield, OH). Plants were watered by hand and reverse osmosis (RO) water was used in all irrigations. At each irrigation plants were fertilized with 20N-3.4P-16.6K at $300 \text{ mg}\cdot\text{L}^{-1}$ for experiments four and five and with $300 \text{ mg}\cdot\text{L}^{-1}$ of 15N-5.4P-14.1K (Peter's Professional, Scotts-Sierra Horticultural Products Company, Marysville, OH) for experiment eight unless toning was required by treatment applied. One week post-planting a broad spectrum fungicide {Etridiazole (5-Ethoxy-3-trichloromethyl-1,2,4-thiadiazole) and Thiophanate {thiophanate-methyl[Dimethyl(1,2-phenylene) bis (iminocarbonothioyl)] bis (carbamate)}}; Banrot 40% WP, Scotts-Sierra Crop Protection Company, Marysville, OH} drench was applied to all plants at $226 \text{ g} / 3.78 \text{ L}$ to prevent root rot diseases. Two weeks post-planting Soluble Trace Element Mixture (STEM, Peter's Professional, Scotts-Sierra Horticultural Products Company, Marysville, OH) drench was applied to all pots at $30 \text{ g}\cdot\text{L}$. Once roots had reached the edge of the pots, imidacloprid {1-[(6-Chloro-3-pyridinyl)methyl]-*N*-nitro-2-imidazolidinimine; Marathon 1% Granular; Olympic Horticultural Products, Mainland, PA} was applied to all plants at 1.4 g/pot for systemic insect control.

Plants were grown in a glass greenhouse until harvest. For all three experiments the greenhouse set points were 24°C day/ 18°C night (Appendix Fig A-5). Throughout experiment four and five and two weeks into production in experiment eight a 50% interior shade cloth was pulled continuously.

At harvest for all experiments plant height and plant width index were measured. Plant height was measured from the base of the pot to the highest point on the plant. Plant width index was the product of two measurements taken perpendicularly across the plant canopy. Buds were defined as any visible flower form before yellow pollen was visible. Open flowers had yellow pollen visible whether the petals were open or partially closed. Senesced flowers had no yellow pollen, all pollen was brown.

Harvest data was analyzed using ANOVA and Least Squared Difference (LSD) test by the SAS program (SAS 8.01; SAS Institute, Cary, NC). Phytotoxicity and quality ratings were analyzed as categorical data in the Proc Genmod procedure of SAS with Chi-Square for mean separation, the quality ratings were analyzed as repeated measure data. In experiment eight repeated measure analysis of flower data was conducted as a split plot design using the Proc Mixed procedure in SAS with LSD for mean separation.

EXPERIMENT 4 – EFFECT OF THIDIAZURON (TDZ) SPRAYS ON QUALITY OF FIVE BRACTEANTHA BRACTEATA CULTIVARS. There were four treatments of thidiazuron (N-phenyl-N'-(1,2,3-thidiazol-5'yl urea), TDZ, Dropp 50WP, Aventis CropScience USA, Research Triangle Park, NC): 2.27, 1.14, 0.23, and 0 μmol (1.0, 0.5, 0.1, and 0.0 $\text{mg}\cdot\text{L}^{-1}$ Dropp) applied on 3 July (28 days post-planting). Each treatment contained seven plants per cultivar. The TDZ was applied as a foliar spray to runoff over the entire plant. They were sprayed when plants reached a mature size but before buds opened. Plants were observed until harvest on 15-18 Aug.

At harvest, number of open flowers, number of chlorotic leaves, and a phytotoxicity rating (Table 51, Fig. 32) were taken on all plants of each cultivar.



Rating 0

Rating 1



Rating 2

Rating 3



Rating 4

Rating 5

Fig. 32. Thidiazuron phytotoxicity ratings on *Bracteantha bracteata* Sundaze series leaves.

Table 51. Phytotoxicity rating from the application of thidiazuron on *Bracteantha bracteata*.

Rating	Plant response
0	All leaves are green and healthy on plant
1	All leaves are green but <25% have depressed areas on the abaxial surface
2	All leaves are green but <25% have depressed areas on the abaxial surface and are twisted
3	>50% leaves are green but many have depressed areas on the abaxial surface, are twisted, and <25% are chlorotic
4	<50% leaves are green, depressed areas on the abaxial surface, are twisted, and growing points are distorted
5	Plant is dead

SPAD (Soil plant analysis development, Minolta SPAD-502 Chlorophyll Meter, Spectrum Technologies, Plainfield, IL) readings from three each of upper, middle, and lower leaves per plant were taken from the 0.23 and 0 μmol treatments of each cultivar. The 2.27 and 1.14 μmol treatments showed sufficient phytotoxicity to make SPAD readings too difficult to take.

EXPERIMENT 5 – TIMING OF NITROGEN TONING ON FIVE BRACTEANTHA BRACTEATA CULTIVARS. Each treatment consisted of ten plants per cultivar. The plants were placed in two treatment blocks

of five plants per cultivar. Each block was randomly assigned to a section of a bench in the greenhouse. The plants were spaced at 1 plant/ 595 cm².

Plants were in production for six full weeks. There were seven nitrogen (N) toning treatments. Nitrogen toning was the cessation of fertilizer during production. Each week, fertilization was terminated for one treatment. Treatments were 0, 1, 2, 3, 4, 5, or 6 weeks of N toning i.e. production without fertilization. When fertilization was terminated plants received plain water until harvest. Treatment 6 was no fertilizer for six weeks; treatment 5 was one week with fertilizer and five weeks of toning; treatment 4 was two weeks with fertilizer and four weeks of toning; treatment 3 was three weeks with fertilizer and three weeks of toning; etc. Before fertilization was terminated, two media samples from each treatment and block for each cultivar were collected and combined. The samples were taken midway between the surface and bottom of the rootball. Saturated paste media extract (SME) technique was done using a Myron L Agri-Meter (Myron L. Company, Carlsbad, CA) to determine the electrical conductivity (EC) and pH of each sample. The samples were stored as recommended (personal communication P.V. Nelson) in airtight containers in a refrigerator at 8 °C until they were analyzed for EC and pH values (Appendix B).

At harvest number of buds, open flowers, senesced flowers, and fresh and dry weights were taken on all plants of each cultivar. SPAD readings from three upper and three lower leaves from one plant of each cultivar of each treatment were taken. Leaf area was measured on five plants per treatment per cultivar with a leaf area meter connected with a transparent belt conveyor (Mod. LI-3000A and LI-3050A, respectively,

LI-COR, Lincoln, Nebr.). Due to the use of only two blocks per treatment the results were pooled and treated as a completely randomized design.

EXPERIMENT 8 – EFFECT OF NITROGEN TONING AND THIDIAZURON ON POSTHARVEST PERFORMANCE OF THREE CULTIVARS OF BRACTEANTHA BRACTEATA. After potting, all the plants were disbudded by removing the terminal flower bud and randomized on two benches. Plants were grown for eight weeks in the greenhouse. The experiment was factorial with three nitrogen toning treatments (0, 4 or 8 weeks nitrogen toning) and three TDZ (0, 2 or 5 μmol) concentrations with seven plants per treatment. Concentrations of TDZ were determined as those used on other potted plants (personal communication Dr. Michael Reid). Plain water from a separate hose was used for the toning treatments to insure no fertilizer was incorporated. Plants toned for 8 weeks were never fertilized. Fertilization was terminated for the 4 week treatment on 29 Mar., after this date the plants were irrigated with plain water. The zero weeks of toning treatment received fertilizer until harvest.

On 2 Apr. the treatments were separated and divided into thidiazuron treatment groups. They were sprayed to runoff over their lower leaves (bottom half of the plant) only with thidiazuron (TDZ analytical standard, Sigma-Aldrich, St Louis, MO). Once dry the plants were randomized on the bench.

Plants were harvested on 20-22 Apr. At harvest and at the end of the postharvest evaluation, data measured included plant height, width index, number of open flowers, number of visible buds, number of senesced flowers and number of chlorotic leaves.

Digital photographs were taken of all treatments and cultivars. SPAD readings were taken from one lower, middle, and upper leaf of all plants in each treatment.

Table 52. Postharvest quality rating.

Rating	Plant response
5	Plant is healthy – no visible decline symptoms
4	No open flowers and/or <10% chlorotic leaves
3	Flower and bud abortion visible over plant and/or <50% lower leaves chlorotic
2	<25% lower leaves senesced, no viable flowers at any stage
1	Senesced lower leaves on bottom half of plant or plant is wilted due to disease
0	Plant has senesced

After harvest plants were moved to a growth room set at 20 °C (actual 15.7 ± 3.5 °C) (Appendix Fig. A-10) and approximately $10 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. The light levels in the growth room were not consistent due to our inability to lower the light levels. Therefore multiple layers of shade cloth were placed over the benches. Plants were randomized on the benches where the light levels were $6\text{-}14 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. Counts of bud number, flower number, senesced flower number, number of chlorotic leaves and a quality rating (Table 52) were taken at five times, hereafter termed postharvest time of measurement.

These postharvest time of measurements included at harvest, after one week, after two weeks, after three weeks, and end (measured the first two days of week four). The quality ratings were only taken on plants toned for zero or four weeks due to the poor starting quality of the plants toned for eight weeks.

At the end of postharvest sample diseased plants were taken to the Plant Disease Diagnostics Lab (Texas A&M University, College Station, TX) for disease diagnosis.

Results

Table 53. Effect of thidiazuron (TDZ) on plant height, width index, number of flowers, and phytotoxicity rating of *Bracteantha bracteata* 'Sundaze Bronze'.

TDZ concentration	Plant height	Plant width index		Phytotoxicity
(μmol)	(cm) ^z	(cm) ^z	No. of flowers ^z	rating ^{yw}
0	31.79	30.18	5.1 a	0.00 c
0.23	31.57	31.71	4.1 ab	1.86 b
1.14	28.64	30.14	3.0 b	4.00 a
2.27	28.79	29.18	0.6 c	4.00 a
Treatment effect ^x	NS	NS	***	***

^z Mean separation in columns by LSD at $P \leq 0.05$.

^y Mean separation in columns by χ^2 at $P \leq 0.05$.

^x NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

^w see Table 51

EXPERIMENT 4 – EFFECT OF THIDIAZURON (TDZ) SPRAYS ON QUALITY OF FIVE BRACTEANTHA BRACTEATA CULTIVARS. ‘Sundaze Bronze’ had no height or width index differences due to TDZ concentration (Table 53). The number of flowers was less for the 1.14 μmol treatment than the control and the 2.27 μmol treatment had the least number of flowers. The phytotoxicity rating increased with each TDZ concentration increase from 0 to 1.14 μmol but there was no difference in rating between the 1.14 and 2.27 μmol treatments.

Table 54. Effect of thidiazuron (TDZ) on plant height, width index, number of flowers, and phytotoxicity rating of *Bracteantha bracteata* 'Sundaze Golden Beauty'.

TDZ concentration (μmol)	Plant height (cm) ^z	Plant width index (cm) ^z	No. of flowers ^z	Phytotoxicity rating ^{yw}
0	30.93 a	38.82 a	4.6 a	0.00 c
0.23	28.29 ab	34.04 b	3.0 a	1.57 b
1.14	20.79 bc	29.39 c	0.7 b	3.71 a
2.27	18.25 c	27.38 c	0.3 b	4.29 a
Treatment effect ^x	**	***	***	***

^z Mean separation in columns by LSD at $P \leq 0.05$.

^y Mean separation in columns by χ^2 at $P \leq 0.05$.

^x NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

^w see Table 51

‘Sundaze Golden Beauty’ had decreased plant height and width index as TDZ concentration increased (Table 54). The number of flowers decreased and the phytotoxicity

rating increased as the concentration of TDZ increased from 0 to 1.14 μmol and there was no difference in flowers or phytotoxicity rating between the 1.14 and 2.27 μmol treatments.

‘Sundaze Golden Yellow’ reacted differently from the other cultivars (Table 55). There was no height difference between 0, 0.23, and 1.14 μmol plants but the 2.27 μmol plants were shorter than the 0 and 1.14 μmol plants. The 1.14 μmol treated plants had a smaller width index than the other plants. The number of flowers was not affected by

Table 55. Effect of thidiazuron (TDZ) on plant height, width index, number of flowers, and phytotoxicity rating of *Bracteantha bracteata* 'Sundaze Golden Yellow'.

TDZ concentration	Plant height	Plant width index	Phytotoxicity	
(μmol)	(cm) ^z	(cm) ^z	No. of flowers ^z	rating ^{yw}
0	30.21 a	35.11 a	2.1	0.00 c
0.23	25.21 ab	34.07 a	1.3	1.43 b
1.14	30.21 a	31.68 b	1.9	2.71 a
2.27	23.00 b	33.50 a	0.6	3.14 a
Treatment effect ^x	*	**	NS	***

^z Mean separation in columns by LSD at $P \leq 0.05$.

^y Mean separation in columns by χ^2 at $P \leq 0.05$.

^x NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

^w see Table 51

TDZ concentration but the phytotoxicity rating increased as the TDZ concentration increased from 0 to 1.14 μmol . As with the other cultivars, there was no difference in phytotoxicity rating between the 1.14 and 2.27 μmol treated plants.

‘Sundaze Pink’ had no height differences due to TDZ concentration (Table 56). The plant width index for the 0, 0.23, and 1.14 μmol treated plants were not different but the 2.27 μmol treated plants had a smaller width than the 0 and 0.23 μmol treated plants. The 2.27 μmol plants had fewer flowers than the 0 and 0.23 μmol plants and the phytotoxicity rating increased with each TDZ concentration increase.

Table 56. Effect of thidiazuron (TDZ) on plant height, width index, number of flowers, and phytotoxicity rating of *Bracteantha bracteata* 'Sundaze Pink'.

TDZ concentration	Plant height	Plant width index		Phytotoxicity
(μmol)	(cm) ^z	(cm) ^z	No. of flowers ^z	rating ^{yw}
0	38.29	35.86 a	7.7 a	0.00 d
0.23	38.93	37.50 a	9.3 a	1.57 c
1.14	33.71	33.79 ab	6.0 ab	3.14 b
2.27	28.42	31.71 b	2.7 b	4.14 a
Treatment effect ^x	NS	*	**	***

^z Mean separation in columns by LSD at $P \leq 0.05$.

^y Mean separation in columns by χ^2 at $P \leq 0.05$.

^x NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

^w see Table 51

'Sundaze White' decreased in height as the TDZ concentration increased (Table 57). There were no differences in width index due to TDZ concentration but the number of flowers decreased when TDZ concentration was 1.14 μmol and greater. Phytotoxicity rating increased as the TDZ concentration increased.

Table 57. Effect of thidiazuron (TDZ) on plant height, width index, number of flowers, and phytotoxicity rating of *Bracteantha bracteata* 'Sundaze White'.

TDZ concentration (μmol)	Plant height (cm) ^z	Plant width index (cm) ^z	No. of flowers ^z	Phytotoxicity rating ^{yw}
0	35.21 a	29.43	8.1 a	0.00 d
0.23	32.64 ab	30.71	8.9 a	1.43 c
1.14	30.43 bc	29.68	3.9 b	3.14 b
2.27	28.57 c	29.54	0.9 c	3.86 a
Treatment effect ^x	**	NS	***	***

^z Mean separation in columns by LSD at $P \leq 0.05$.

^y Mean separation in columns by χ^2 at $P \leq 0.05$.

^x NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

^w see Table 51

SPAD values were taken on the 0 and 0.23 μmol treatments due to the extreme phytotoxic response of the cultivars to the higher concentrations of TDZ. For all cultivars, SPAD values taken from the lower leaves of the 0.23 μmol treated plants were higher than those measured on the control leaves (Tables 58-62). The SPAD readings of

Table 58. Effect of thidiazuron (TDZ) on SPAD values for lower, middle and upper leaves and chlorotic leaves per plant on *Bracteantha bracteata* 'Sundaze Bronze'.

TDZ concentration (μmol)	SPAD value for leaf position			Chlorotic leaves per plant (no.)
	lower	middle	upper	
0	38.786	42.614	43.357	4.7
0.23	45.457	51.457	47.271	2.2
Treatment effect	**	***	NS	*
LSD	4.4	4.1	5.8	2.0

Mean separation in columns by LSD at $P \leq 0.05$.

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

Table 59. Effect of thidiazuron (TDZ) on SPAD values for lower, middle and upper leaves and chlorotic leaves per plant on *Bracteantha bracteata* 'Sundaze Golden Beauty'.

TDZ concentration (μmol)	SPAD value for leaf position			Chlorotic leaves per plant (no.)
	lower	middle	upper	
0	38.671	40.500	42.971	8.3
0.23	45.143	45.386	45.300	3.3
Treatment effect	*	*	NS	**
LSD	5.4	4.3	4.6	2.6

Mean separation in columns by LSD at $P \leq 0.05$.

NS, *, ** Non-significant or significant at $P \leq 0.05, 0.01$, respectively.

Table 60. Effect of thidiazuron (TDZ) on SPAD values for lower, middle and upper leaves and chlorotic leaves per plant on *Bracteantha bracteata* 'Sundaze Golden Yellow'.

TDZ concentration (μmol)	SPAD value for leaf position			Chlorotic leaves per plant (no.)
	lower	middle	upper	
0	49.186	51.300	48.500	3.7
0.23	52.886	55.229	49.729	3.3
Treatment effect	*	NS	NS	NS
LSD	3.3	5.6	4.5	2.3

Mean separation in columns by LSD at $P \leq 0.05$.

NS, * Nonsignificant or significant at $P \leq 0.05$ respectively.

Table 61. Effect of thidiazuron (TDZ) on SPAD values for lower, middle and upper leaves and chlorotic leaves per plant on *Bracteantha bracteata* 'Sundaze Pink'.

TDZ concentration (μmol)	SPAD value for leaf position			Chlorotic leaves per plant (no.)
	lower	middle	upper	
0	44.014	47.029	43.971	4.1
0.23	49.329	51.057	49.214	3.1
Treatment effect	*	NS	NS	NS
LSD	4.1	6.3	5.7	2.0

Mean separation in columns by LSD at $P \leq 0.05$.

NS, * Nonsignificant or significant at $P \leq 0.05$ respectively.

Table 62. Effect of thidiazuron (TDZ) on SPAD values for lower, middle and upper leaves and chlorotic leaves per plant on *Bracteantha bracteata* 'Sundaze White'.

TDZ concentration (μmol)	SPAD value for leaf position			Chlorotic leaves per plant (no.)
	lower	middle	upper	
0	53.429	55.686	51.886	10.4
0.23	61.200	63.543	57.100	4.6
Treatment effect	**	**	NS	***
LSD	4.6	4.6	8.3	1.9

Mean separation in columns by LSD at $P \leq 0.05$.

NS, **, *** Nonsignificant or significant at $P \leq 0.01$, 0.001, respectively.

the middle leaves of treated plants were higher for 'Bronze' (Table 58), 'Golden Beauty' (Table 59), and 'White' (Table 60). 'Golden Yellow' (Table 61) and 'Pink' (Table 62) had no difference between the treated and control middle leaves while no cultivars had differences between treatments on the upper leaves. This lack of differences was because the 0 μmol upper leaves were green and showed no chlorosis. The number of chlorotic leaves per plant ranged from 40% to 47% less on TDZ treated plants for 'Bronze', 'Golden Beauty' and 'White'. 'Golden Yellow' and 'Pink' plants treated with 0 μmol did not have as many chlorotic leaves as 'Golden Beauty' and 'White'. The 1.14 and 2.27 μmol concentrations of TDZ caused phytotoxic responses on all five cultivars. All cultivars were given phytotoxicity ratings of three or four at those concentrations. The 0.23 μmol TDZ treated plants had some TDZ phytotoxic responses

Table 63. Effect of weeks of nitrogen toning on growth and development of *Bracteantha bracteata* 'Sundaze Bronze' at harvest.

Weeks of nitrogen toning	Plant height	Plant width index	Leaf area	Fresh weight	Dry weight	Number of flowers			
	(cm)	(cm)	(cm ²)	(g)	(g)	Open	Buds	Senesced	Total
0	32.40 a	32.90 a	13420	121.0 a	18.0 a	7.2 a	24.0 a	3.0	34.2 a
1	31.80 ab	29.25 b	2401	86.4 b	13.9 b	4.9 bc	17.0 b	2.7	24.6 b
2	30.67 abc	27.94 b	1629	76.0 bc	13.9 b	6.6 ab	13.9 bc	3.0	23.4 b
3	28.65 bcd	27.10 b	1360	68.3 c	12.4 b	5.9 ab	10.9 cd	2.5	19.3 c
4	29.25 abc	22.00 c	1245	28.9 d	6.8 cd	2.7 d	7.3 de	1.3	10.7 d
5	27.95 cd	21.40 c	347	30.7 d	7.9 c	3.8 cd	6.7 de	2.2	13.3 d
6	25.30 d	18.36 d	194	17.0 e	4.8 d	2.2 d	3.5 e	1.1	6.8 e
Treatment effect	***	***	NS	***	***	***	***	NS	***
LSD	3.2	2.2	11529	11.4	2.1	2.1	4.3	1.8	7.4

Mean separation in columns by LSD at $P \leq 0.05$.

NS, *** Nonsignificant or significant at $P \leq 0.001$, respectively.

Table 33. Effect of weeks of nitrogen toning on growth and development of *Bracteantha bracteata* 'Sundaze Golden Beauty' at harvest.

Weeks of nitrogen toning	Plant height (cm)	Plant width		Fresh weight (g)	Dry weight (g)	Number of flowers			
		index (cm)	Leaf area (cm ²)			Open	Buds	Senesced	Total
0	29.15 c	38.15 a	1660.7 a	98.1 a	13.0 a	3.0 c	23.4 a	5.2 a	31.6 a
1	35.15 ab	36.43 a	1277.2 b	87.1 b	12.8 ab	4.4 abc	16.3 b	5.0 a	25.7 b
2	35.15 ab	32.15 b	918.2 c	68.5 c	11.5 bc	5.3 a	11.6 c	4.6 a	21.5 c
3	36.00 ab	31.03 b	936.0 c	64.0 c	10.8 c	5.0 ab	10.1 c	4.9 a	20.0 c
4	36.55 a	25.58 c	407.3 d	29.5 d	6.4 d	4.3 abc	3.1 d	2.9 b	10.3 d
5	35.20 ab	23.33 c	391.7 d	29.0 d	6.9 d	3.4 bc	3.4 d	3.9 ab	10.7 d
6	33.65 b	16.80 d	152.4 e	11.3 e	3.0 e	1.1 d	1.3 d	2.6 b	5.0 e
Treatment effect	***	***	***	***	***	***	***	**	***
LSD	2.6	2.7	164.4	2.0	1.4	1.6	2.6	1.5	3.2

Mean separation in columns by LSD at $P \leq 0.05$.

, * Significant at $P \leq 0.01$, 0.001 , respectively.

with all cultivars given ratings of one or two but benefits were also seen as the treated leaves were a darker green. Height and/or width index and number of flowers decreased as the TDZ concentration increased for four out of five cultivars. The higher SPAD value for the 0.23 μmol plants indicated a higher level of chlorophyll in the treated leaves and corresponded to an increased greenness of the leaves observed visually.

EXPERIMENT 5 – TIMING OF NITROGEN TONING ON FIVE BRACTEANTHA BRACTEATA CULTIVARS. Vegetative growth was changed with different number of weeks of nitrogen toning for the cultivars. One week of nitrogen toning of ‘Sundaze Bronze’ reduced width index, fresh weight, and dry weight compared to plants that were not toned (Table 63), these reductions continued with increasing weeks of nitrogen toning. Height did not change until three weeks of toning. On ‘Sundaze Golden Beauty’ the leaf area and fresh weight decreased after one week of nitrogen toning compared to no weeks of nitrogen toning (Table 64). Compared to the controls, the width index and dry weight decreased after two weeks of nitrogen toning. Plant height increased when plants were toned for one or more weeks. ‘Sundaze Golden Yellow’ had decreased leaf area with one week of toning when compared to the control (Table 65). Width index and fresh weight were decreased with two weeks of nitrogen toning and dry weight decreased with three weeks of toning compared to the control. Plant height was not affected until plants were toned for five weeks. ‘Sundaze Pink’ had a decrease in leaf area and fresh weight with one week of toning (Table 66). There was no difference in height due to toning, The width index and dry weight decreased on plants toned for two weeks compared to plants that were not toned. ‘Sundaze White’ had a decrease in leaf area and fresh weight

Table 65. Effect of weeks of nitrogen toning on growth and development of *Bracteantha bracteata* 'Sundaze Golden Yellow' at harvest.

Weeks of nitrogen toning	Plant height (cm)	Plant width index (cm)	Leaf area (cm ²)	Fresh weight (g)	Dry weight (g)	Number of flowers			
						Open	Buds	Senesced	Total
0	26.35 ab	34.65 a	2813.8 a	139.0 a	14.9 a	1.2 bc	7.5 a	0.8	9.5 ab
1	27.20 ab	34.30 ab	2264.2 b	124.9 a	13.6 a	2.0 ab	5.4 ab	0.7	8.1 abc
2	28.80 a	32.55 b	2008.3 b	95.3 b	13.5 a	3.0 a	5.8 ab	2.6	11.4 a
3	26.10 ab	29.75 c	1432.8 c	76.6 c	9.9 b	1.8 b	4.2 bc	0.6	6.6 bcd
4	25.55 ab	24.40 d	587.1 d	35.3 d	5.7 c	1.6 b	3.2 cd	1.4	6.2 bcd
5	24.90 bc	20.63 e	488.2 d	27.9 de	4.6 c	1.1 bc	2.7 cd	0.7	4.5 dc
6	21.35 c	18.28 f	223.2 d	13.6 e	2.2 d	0.1 c	1.8 d	0.8	2.7 d
Treatment effect	*	***	***	***	***	***	***	NS	**
LSD	3.8	1.8	401.8	16.6	1.8	1.2	2.2	1.7	4.2

Mean separation in columns by LSD at $P \leq 0.05$.

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

Table 66. Effect of weeks of nitrogen toning on growth and development of *Bracteantha bracteata* 'Sundaze Pink' at harvest.

Weeks of nitrogen toning	Plant height	Plant width index	Leaf area (cm ²)	Fresh weight	Dry weight	Number of flowers			
	(cm)	(cm)		(g)	(g)	Open	Buds	Senesced	Total
0	35.35	36.13 a	2932.4 a	124.6 a	16.8 ab	9.5 ab	24.8 a	7.2 abc	41.5 a
1	39.05	35.23 a	2256.3 b	108.4 b	17.3 a	10.6 a	16.8 b	7.5 ab	34.9 b
2	33.55	30.08 b	1812.8 c	87.6 c	15.1 b	10.5 a	16.6 b	8.5 a	35.6 ab
3	32.15	29.10 b	1343.1 d	70.8 d	12.3 c	10.4 a	9.0 c	6.2 bc	25.6 c
4	33.45	25.98 c	825.0 e	43.3 e	8.8 d	7.3 b	6.3 cd	5.4 cd	19.0 d
5	34.55	22.40 d	405.8 f	35.8 e	8.0 d	4.6 c	5.3 cd	5.3 cd	15.2 d
6	34.55	19.10 e	254.7 f	17.2 f	4.2 e	1.5 d	3.2 d	4.1 d	8.8 e
Treatment effect	NS	***	***	***	***	***	***	**	***
LSD	4.5	2.4	351.3	12.4	2.0	2.6	3.7	2.1	6.2

Mean separation in columns by LSD at $P \leq 0.05$.

NS, **, *** Nonsignificant or significant at $P \leq 0.01, 0.001$, respectively.

Table 67. Effect of weeks of nitrogen toning on growth and development of *Bracteantha bracteata* 'Sundaze White' at harvest.

Weeks of nitrogen toning	Plant height (cm)	Plant width		Fresh weight (g)	Dry weight (g)	Number of flowers			
		index (cm)	Leaf area (cm ²)			Open	Buds	Senesced	Total
0	32.85 a	29.70 a	1548.4 a	106.0 a	14.1 a	8.2 a	14.5 a	7.0 bc	29.7 a
1	31.50 ab	28.60 ab	1190.3 b	83.1 b	12.7 ab	8.3 a	13.0 ab	9.7 a	31.0 a
2	31.95 ab	27.03 bc	1055.9 b	78.2 b	12.7 ab	9.7 a	11.0 bc	8.7 ab	29.4 a
3	32.95 a	25.10 c	1214.0 b	76.8 b	11.5 b	5.9 b	10.4 c	3.9 d	20.2 b
4	28.75 bc	19.05 d	396.0 c	31.0 c	6.2 c	4.1 bc	4.4 d	4.8 cd	13.3 c
5	27.50 cd	17.30 d	301.1 cd	28.5 c	6.1 c	3.2 c	3.8 d	5.8 cd	12.8 cd
6	24.70 d	12.98 e	149.6 d	13.0 d	3.1 d	2.4 c	2.4 d	3.2 d	8.0 d
Treatment effect	***	***	***	***	***	***	***	***	***
LSD	3.4	2.2	230.2	10.5	1.6	2.0	2.5	2.6	5.1

Mean separation in columns by LSD at $P \leq 0.05$.

*** Significant at $P \leq 0.001$.

with one week of toning (Table 67). The width index decreased with two weeks of toning and dry weight with three weeks of toning compared to the controls. There was no decrease in plant height between toning treatments until plants were toned for four weeks.

Reproductive growth of 'Sundaze Bronze' was decreased for the number of buds, open flowers and total flowers with one week of toning compared to plants that were not toned. There was no effect of toning on the number of senesced flowers. On 'Sundaze Golden Beauty' the number of open flowers increased on the plants toned for two weeks. The number of buds and total number of flowers decreased with one week of toning. The number of senesced flowers decreased on plants toned for four weeks compared to plants that were not toned. 'Sundaze Golden Yellow' increased in number of open flowers on plants toned for two weeks when compared to plants that were not toned. The number of buds decreased on plants toned for three weeks while total number of flowers was not different from those not toned until plants were toned for five weeks. Senesced flowers did not differ on 'Sundaze Golden Yellow'. The number of open flowers on 'Sundaze Pink' decreased on plants toned for four weeks while the number of buds decreased with one week of toning. The number of senesced flowers decreased on plants toned for six weeks. The total number of flowers decreased on plants toned for three weeks when compared to plants that were not toned. On 'Sundaze White' the number of open flowers and total flowers decreased on plants toned for three weeks. The number of senesced flowers decreased on plants toned for two weeks while the number of senesced flowers increased on plants toned for one week and decreased on

plants toned for three weeks when compared to plants that were not toned. From these results it appears between one and three weeks of toning reduced vegetative growth of most factors measured on the cultivars. Toning between one and three weeks would not affect total number of flowers on most of the cultivars.

The EC readings were erratic (Appendix B). In general, the treatments toned the longest had the lowest EC readings. The readings spiked around week three or four but decreased afterwards. The decrease in EC in later weeks may have been due to leeching as plants matured and more frequent watering was needed. The pH readings went up from between 5.5 and 6.0 to between 6.5 and 7.0 as the experiment progressed.

EXPERIMENT 8 – EFFECT OF NITROGEN TONING AND THIDIAZURON ON POSTHARVEST PERFORMANCE OF THREE CULTIVARS OF *BRACTEANTHA BRACTEATA*. At harvest, there was no effect nitrogen toning on plant height of the three bracteantha cultivars. In general, as weeks of toning increased width index decreased for all cultivars (Table 68). The only TDZ effect on height or width index was on ‘Sundaze Pink’ width index. Plants treated with 2 μmol TDZ were 31.48 cm wide while plants treated with 5 μmol TDZ were significantly smaller at 28.88 cm wide. Plants treated with 0 μmol were 30.19 cm wide and not different from the other TDZ treatments.

Table 68. Effect of weeks of nitrogen toning on plant height and width index at harvest of *Bracteantha bracteata* ‘Sundaze Bronze’, ‘Sundaze Pink’ and ‘Sundaze White’.

Weeks of nitrogen toning	Sundaze Bronze		Sundaze Pink		Sundaze White	
	Height (cm)	Width index (cm)	Height (cm)	Width index (cm)	Height (cm)	Width index (cm)
0	33.31	22.62 c	31.12	27.36 c	29.48	25.61 c
4	31.93	27.69 b	28.83	32.15 b	28.48	30.42 b
8	32.55	30.35 a	30.60	35.40 a	30.36	34.14 a
Nitrogen toning	NS	***	NS	***	NS	***
Thidiazuron	NS	NS	NS	*	NS	NS
Nitrogen toning x thidiazuron	NS	NS	NS	NS	NS	**

Mean separation in columns by LSD at $P \leq 0.05$.

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

Thidiazuron was sprayed on the lower leaves of the plants and not on the reproductive growth. Thidiazuron had little effect on reproductive parameters measured at harvest. Nitrogen toning affected reproductive growth in number of buds only of the cultivars evaluated. In general the number of buds declined as weeks of nitrogen toning increased for all three cultivars (Table 69). The number of flowers on ‘Bronze’, ‘Pink’, and ‘White’ were not significant. The number of senesced flowers were not significant and averaged 0.56, 0.56 and 0.40 on ‘Bronze’, ‘Pink’, and ‘White’ respectively, at harvest.

Table 69. Effect of weeks of nitrogen toning on number of buds, flowers and chlorotic leaves at harvest on *Bracteantha bracteata* ‘Sundaze Bronze’, ‘Sundaze Pink’ and ‘Sundaze White’.

Weeks of nitrogen toning	Sundaze Bronze			Sundaze Pink			Sundaze White		
	Bud (no.)	Flower (no.)	Chlorotic	Bud (no.)	Flower (no.)	Chlorotic	Bud (no.)	Flower (no.)	Chlorotic
			leaves (no.)			leaves (no.)			leaves (no.)
0	21.7 a	1.5	0.1 c	14.7 a	3.1	0.3 b	18.9 a	4.1	5.7 c
4	14.1 b	1.3	3.9 b	10.1 b	3.7	7.3 ab	14.5 b	3.0	9.4 b
8	7.8 c	1.5	13.1 a	4.8 c	4.1	15.0 a	7.6 c	3.7	13.0 a
Nitrogen toning	***	NS	***	***	NS	***	***	NS	***
Thidiazuron	NS	NS	NS	*	NS	NS	**	NS	***
Nitrogen toning x thidiazuron	NS	NS	*	NS	NS	*	*	NS	NS

Mean separation in columns by LSD at $P \leq 0.05$.

NS, *** Nonsignificant or significant at $P \leq 0.001$, respectively.

The repeated measure analysis of number of chlorotic leaves due to nitrogen toning only found differences between treatments at harvest therefore they will be discussed with harvest data. On ‘Sundaze Bronze’ and ‘Sundaze White’ the number of chlorotic leaves decreased as weeks of nitrogen toning decreased. On ‘Sundaze Pink’ plants toned with zero weeks of nitrogen toning had less chlorotic leaves than plants toned for eight weeks. Plants toned for four weeks had no difference from those toned zero or eight weeks.

Table 70. Effect of weeks of nitrogen toning on SPAD reading measurements of *Bracteantha bracteata* ‘Sundaze Bronze’, ‘Sundaze Pink’ and ‘Sundaze White’ taken at harvest.

Weeks of nitrogen toning	Sundaze Bronze			Sundaze Pink			Sundaze White		
				Leaf measurement location					
	Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
0	42.267 a	40.452 a	35.590 a	36.814 a	41.548 a	39.810 a	41.276	46.138	44.600 a
4	37.695 b	38.462 a	32.971 a	34.133 a	40.119 a	39.752 a	40.809	46.616	45.819 a
8	31.733 c	31.733 b	27.986 b	30.690 b	36.029 b	35.610 b	43.075	48.191	40.500 b
Nitrogen toning	***	***	***	***	**	*	NS	NS	**
Nitrogen toning x thidiazuron	NS	NS	NS	NS	NS	NS	NS	NS	NS

Mean separation in columns by LSD at $P \leq 0.05$.

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$ respectively.

Nitrogen toning affected SPAD readings for all three leaf measurement locations on ‘Bronze’ and ‘Pink’ but only the upper leaves of ‘White’ (Table 70). In the lower leaves of ‘Bronze’ as weeks of nitrogen toning increased the SPAD level decreased. In all other leaves of the three cultivars four weeks of toning gave the same SPAD reading as zero weeks of toning. Since SPAD readings indicate chlorophyll levels these results indicate four weeks of nitrogen toning did not affect the amount of chlorophyll or leaf chlorosis in the plants.

Table 71. Effect of thidiazuron (TDZ) on SPAD reading measurements of *Bracteantha bracteata* ‘Sundaze Bronze’, ‘Sundaze Pink’ and ‘Sundaze White’ taken at harvest.

TDZ concentration (μmol)	Sundaze Bronze			Sundaze Pink			Sundaze White		
				Leaf measurement location					
	Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
0	39.952 a	37.567	32.343	30.933 b	40.257	39.343	39.438	46.448	45.138 a
2	34.233 b	35.167	31.667	35.186 a	39.942	38.833	41.228	47.005	45.162 a
5	37.510 ab	38.424	32.538	35.519 a	37.495	36.995	44.495	47.502	40.619 b
Thidiazuron	*	NS	NS	**	NS	NS	NS	NS	**
Nitrogen toning x thidiazuron	NS	NS	NS	NS	NS	NS	NS	NS	NS

Mean separation in columns by LSD at $P \leq 0.05$.

NS, *, ** Nonsignificant or significant at $P \leq 0.05$, 0.01 , respectively.

The lower leaf SPAD readings of ‘Bronze’ and ‘Pink’ and the upper leaves of ‘White’ were affected by TDZ at harvest (Table 71). Treatment with either concentration of TDZ increased SPAD readings in ‘Pink’ but in ‘Bronze’ treatment with $2 \mu\text{mol}$ increased SPAD readings but there was no difference in readings between 0 and $5 \mu\text{mol}$ treatments. ‘White’ reacted differently than the other cultivars. It had a decrease in SPAD reading on upper leaves treated with $5 \mu\text{mol}$ TDZ compared to the other treatments. This result on the upper leaves is less important because it is the lower leaves where damaging symptoms of chlorosis are seen in bracteantha.

Table 72. Effect of weeks of nitrogen toning on SPAD reading measurements of *Bracteantha bracteata* ‘Sundaze Bronze’, ‘Sundaze Pink’ and ‘Sundaze White’ taken at the end of the postharvest evaluation.

Weeks of nitrogen toning	Sundaze Bronze			Sundaze Pink			Sundaze White		
	Leaf measurement location			Leaf measurement location			Leaf measurement location		
	Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
0	43.964 a	36.518 a	34.282 a	33.138	36.852	40.900 ab	38.871	42.200	51.942 a
4	36.200 b	34.662 a	33.862 a	33.824	39.505	42.476 a	40.300	42.400	48.353 b
8	28.300 c	28.886 b	29.181 b	37.075	40.608	38.190 b	44.700	46.500	43.476 c
Nitrogen toning	***	***	**	NS	NS	*	NS	NS	***
Nitrogen toning x thidiazuron	NS	NS	NS	NS	NS	NS	NS	NS	NS

Mean separation in columns by LSD at $P \leq 0.05$.

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

At the end of the postharvest evaluation nitrogen toning affected ‘Bronze’ SPAD readings at all three leaf measurement locations, ‘Pink’ and ‘White’ had a toning effects on upper leaves (Table 72). The differences between treatments seen at harvest on ‘Bronze’ were still seen at the end of postharvest. The upper leaves of ‘Pink’ and ‘White’ still had decreased SPAD readings as weeks of nitrogen toning increased.

Thidiazuron affected SPAD readings on ‘Pink’ lower leaves and ‘White’ lower and middle leaves at the end of the postharvest evaluation (Table 73). SPAD readings increased with application of TDZ at either concentration. SPAD readings for ‘Bronze’ were not affected by TDZ by the end of postharvest.

Table 73. Effect of thidiazuron (TDZ) on SPAD reading measurements of *Bracteantha bracteata* ‘Sundaze Bronze’, ‘Sundaze Pink’ and ‘Sundaze White’ taken at the end of postharvest evaluation.

TDZ concentration (μmol)	Sundaze Bronze			Sundaze Pink			Sundaze White		
				Leaf measurement location					
	Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
0	30.707	32.747	31.427	29.712 a	38.824	41.900	36.493 a	39.236 a	46.400
2	35.211	32.705	33.068	36.655 b	39.595	40.475	41.432 b	45.579 b	48.684
5	37.289	32.821	31.647	36.053 b	37.582	39.000	43.174 b	43.921 b	46.337
Thidiazuron	NS	NS	NS	***	NS	NS	*	*	NS
Nitrogen toning x thidiazuron	NS	NS	NS	NS	NS	NS	NS	NS	NS

Mean separation in columns by LSD at $P \leq 0.05$.

NS, *, ** Nonsignificant or significant at $P \leq 0.05, 0.01$, respectively.

In repeated measure analysis ‘Sundaze Bronze’ had a three way interaction in quality and ‘Sundaze White’ had three way interactions in quality and chlorotic leaves (Table 74). ‘Sundaze Bronze’, ‘Sundaze Pink’, and ‘Sundaze White’ had interactions between nitrogen toning and postharvest time of measurement in quality. For ‘Sundaze Bronze’, quality on plants toned zero weeks decreased each week after one week postharvest and at three weeks postharvest was no longer marketable (Table 75). The quality of plants toned four weeks decreased but remained high throughout postharvest and was greater than plants not toned at two and three weeks postharvest.

Table 74. Repeated measure F-test for quality rating and number of chlorotic leaves on *Bracteantha bracteata* ‘Sundaze Bronze’, ‘Sundaze Pink’, and ‘Sundaze White’.

	Sundaze Bronze		Sundaze Pink		Sundaze White	
	Chlorotic		Chlorotic		Chlorotic	
	Quality	leaves	Quality	leaves	Quality	leaves
	rating	(no.)	rating	(no.)	rating	(no.)
Thidiazuron	**	**	NS	*	*	***
Nitrogen toning	***	**	*	***	NS	NS
Postharvest time of measurement	***	NS	***	*	***	***
Thidiazuron x postharvest time of measurement	**	*	NS	NS	*	NS
Thidiazuron x toning	NS	NS	NS	NS	*	**
Toning x postharvest time of measurement	***	***	***	***	*	***
Thidiazuron x toning x postharvest time of measurement	***	NS	NS	NS	*	*

NS, *, ** Nonsignificant or significant at $P \leq 0.05$, 0.01 , respectively.

Table 75. Effect of nitrogen toning and postharvest time of measurement on quality rating of *Bracteantha bracteata* ‘Sundaze Bronze’.

Weeks of nitrogen toning	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
0	5.00 A a	5.00 A a	4.05 B b	1.95 B c
4	5.00 A a	4.76 A abc	4.76 A b	4.33 A c

Mean separation in columns (uppercase letters) and rows (lower case letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

Table 76. Effect of nitrogen toning and postharvest time of measurement on quality rating of *Bracteantha bracteata* ‘Sundaze Pink’.

Weeks of nitrogen toning	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
0	5.00 A a	4.91 A b	4.33 A c	2.29 B d
4	5.00 A a	4.67 B b	4.19 A c	4.09 A c

Mean separation in columns (uppercase letters) and rows (lower case letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

For ‘Sundaze Pink’ the quality decreased at each postharvest time of measurement for both toning treatments until two weeks postharvest (Table 76). One week postharvest, plants toned for zero weeks had a higher quality than those toned for four weeks. Three weeks postharvest plants toned for four weeks had maintained a higher quality than those toned for zero weeks, which were no longer marketable.

Table 77. Effect of nitrogen toning and postharvest time of measurement on quality rating of *Bracteantha bracteata* ‘Sundaze White’.

Weeks of nitrogen toning	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
0	5.00 A a	4.95 A b	3.76 A c	1.81 B d
4	5.00 A a	4.81 B b	4.00 A c	3.09 A d

Mean separation in columns (uppercase letters) and rows (lower case letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

For ‘Sundaze White’ the quality ratings of the two toning treatments followed a similar pattern (Table 77). They declined each week postharvest. Three weeks postharvest the plants toned for four weeks maintained a marketable quality but not so for those toned for zero weeks.

There was an interaction between TDZ and postharvest time of measurement for the quality of ‘Sundaze Bronze’ and ‘Sundaze White’ (Table 74). ‘Sundaze Pink’ had no effect on quality due to TDZ. For ‘Sundaze Bronze’ the control (0 μmol TDZ) had a decrease in quality at each postharvest time of measurement and was no longer marketable after three weeks (Table 78). The 2 and 5 μmol treatments remained at a rating of 5.00 for one week, 4.50 and 4.64, respectively, for two weeks and marketable through the third week postharvest. There was no difference in quality between these

Table 78. Effect of thidiazuron (TDZ) concentration and postharvest time of measurement on quality rating of *Bracteantha bracteata* ‘Sundaze Bronze’.

Thidiazuron concentration (μmol)	Time of postharvest measurement			
	Harvest	One week	Two weeks	Three weeks
0	5.00 A a	4.64 B b	4.07 B c	2.07 B d
2	5.00 A a	5.00 A a	4.50 AB b	3.79 A c
5	5.00 A a	5.00 A a	4.64 A d	3.57 A c

Mean separation in columns (uppercase letters) and rows (lower case letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

two treatments throughout the entire postharvest period. The control (0 μmol TDZ) was lower in quality than the other treatments at one week and thereafter, it was no longer marketable after three weeks.

For ‘Sundaze White’ there was a decline in quality of the control (0 μmol TDZ) and the 2 μmol TDZ treatments after one week postharvest (Table 79). The 5 μmol TDZ treatment held a 5.00 quality rating until two weeks postharvest. The 0 μmol TDZ plants declined in quality more than the other treatments two and three weeks postharvest. None of the treatments were marketable after three weeks postharvest.

Table 79. Effect of thidiazuron (TDZ) concentration and postharvest time of measurement on quality rating of *Bracteantha bracteata* ‘Sundaze White’.

TDZ concentration					
(μmol)	Harvest	One week	Two weeks	Three weeks	
0	5.00 A a	4.79 B b	3.21 B c	1.93 B d	
2	5.00 A a	4.86 B b	4.21 A c	2.71 A d	
5	5.00 A a	5.00 A a	4.21 A b	2.71 A c	

Mean separation in columns (uppercase letters) and rows (lower case letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

There were interactions between nitrogen toning and postharvest time of measurement for number of chlorotic leaves for all cultivars (Table 74). However, the interactions were generally due to the plants that had eight weeks of toning, i.e. never fertilized, having more chlorotic leaves at harvest which decreased to senescent leaves

causing a decline. Chlorotic leaves of the plants toned for zero or four weeks stayed the same through the postharvest evaluation.

Table 80. Effect of thidiazuron (TDZ) concentration on number of chlorotic leaves on *Bracteantha bracteata* ‘Sundaze Bronze’ and ‘Sundaze Pink’ postharvest.

TDZ concentration (μmol)	Number of chlorotic leaves	
	Sundaze Bronze	Sundaze Pink
0	5.58 a	7.75 a
2	5.60 a	5.99 ab
5	3.82 b	5.31 b
Treatment effect	**	*

Mean separation in columns by LSD at $P \leq 0.05$.

*, ** Significant at $P \leq 0.05$, 0.01 , respectively.

There was a TDZ concentration and postharvest time of measurement interaction on number of chlorotic leaves on ‘Sundaze Bronze’ (Table 74). However, the treatments were not different at any point in time or over time. A main effect due to TDZ concentration was significant on ‘Sundaze Bronze’ and ‘Sundaze Pink’ (Table 80). For ‘Sundaze Bronze’ plants treated with $5 \mu\text{mol}$ TDZ had less chlorotic leaves than plants treated with 0 or $2 \mu\text{mol}$ TDZ. ‘Sundaze Pink’ plants treated with $5 \mu\text{mol}$ TDZ had fewer chlorotic leaves than those treated with $0 \mu\text{mol}$ TDZ while neither was different from the $2 \mu\text{mol}$ TDZ plants.

There was an interaction between TDZ concentration and nitrogen toning on quality rating ‘Sundaze White’. There was a difference in between plants treated with 0 or 2 μmol TDZ when they were toned for four weeks (Table 81). On plants toned for zero weeks, the 0 μmol TDZ treatment had a lower quality rating than the other TDZ treatments. The quality rating decreased with 0 weeks of toning on plants treated with 0 or 2 μmol TDZ. Quality ratings were the same between toning lengths on plants treated with 5 μmol TDZ.

Table 81. Effect of concentration of thidiazuron and nitrogen toning on quality ratings on ‘Sundaze White’.

Weeks of nitrogen toning	<u>Thidiazuron concentration (μmol)</u>		
	0	2	5
4	4.14 A b	4.36 A a	4.18 A ab
0	3.32 B b	4.04 B a	4.29 A a

Mean separation in columns (uppercase letters) and rows (lower case letters) by χ^2 at $P \leq 0.05$.

Quality of 5=best, <3 = not marketable, 0=death.

There was an interaction between TDZ concentration and nitrogen toning on number of chlorotic leaves (Fig 33). There was no difference among TDZ concentrations in number of chlorotic leaves on plants toned for eight weeks. These plants had fewer total leaves than plants toned for zero or four weeks. Plants toned for four weeks or not toned had more chlorotic leaves when plants were not treated with TDZ. As concentration of TDZ increased the number of chlorotic leaves decreased on plants not toned or toned for four weeks.

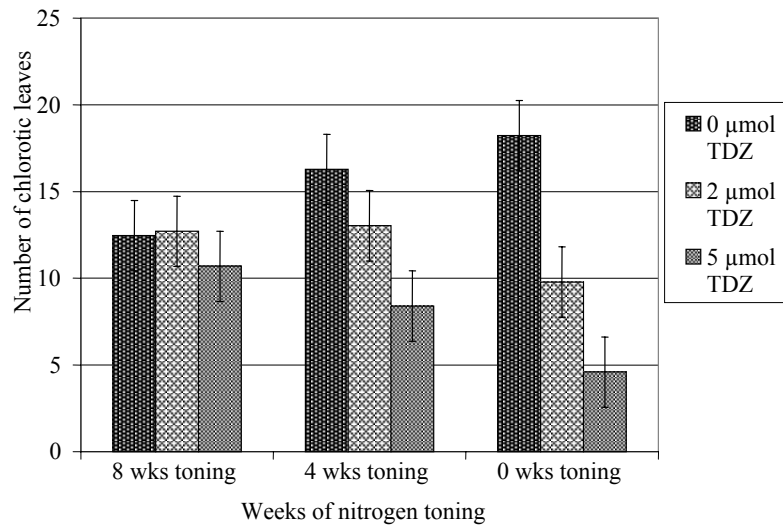


Fig. 33. Effect of concentration of thidiazuron (TDZ) and nitrogen toning on number of chlorotic leaves on 'Sundaze White'.

Table 82. Effect of thidiazuron (TDZ) concentration on *Bracteantha bracteata* cultivars that were nitrogen toned for zero weeks on percentage of dead plants due to *Botrytis* spp. (Gray Mold disease) infestation.

TDZ concentration (μmol)	Sundaze Cultivars (% dead plants)		
	Bronze	White	Pink
0	86%	71%	57%
2	29%	29%	14%
5	29%	29%	57%

On all cultivars, *Botrytis* spp. (Gray mold disease) occurred at the crown and on the stem of plants postharvest causing the entire plant to senesce. The plants that had zero weeks of toning were most affected (Table 82).

Discussion

In experiment four, Dropp at concentrations of 0.23 μmol caused growth responses in plants while higher rates (1.14 and 2.27 μmol) elicited phytotoxic responses. These seemingly low concentrations of TDZ were not expected to cause phytotoxicity. Factors other than chemical concentration may have been involved. The carrier may have evaporated leaving the chemical accumulated on the leaves in the heat of the greenhouse during the summer. The plants were sprayed in the early morning but the greenhouse was still hot (24.7 °C for expt. 4 compared to 19.7 °C for expt. 8).

The SPAD results do indicate a positive response of chlorophyll to TDZ on lower and middle but not upper leaves. Upper leaves were dark green before treatment indicating high levels of chlorophyll and these leaves may not have had the capacity to increase chlorophyll production after TDZ treatment. There were also less number of chlorotic leaves on TDZ treated plants which is in line with what Ferrante et al. (2003) found on cut tulips and chrysanthemums. The vegetative growth reduction on plants treated with Dropp is a side benefit of application; however the effects on leaf chlorosis and senescence are why a grower may consider using TDZ on their crops. No reporting of a phytotoxic response in ornamentals was found in the literature. However, TDZ is used at high concentrations in cotton production for defoliation and Banko and Stefani (1999) found using Dropp at 800 $\text{mg}\cdot\text{L}^{-1}$ would defoliated holly for the cut flower market. Thidiazuron did not affect the

flower number on ‘Sundaze Golden Yellow’, this could be due to the plant habit. ‘Golden Yellow’ has a more rosette habit than the other cultivars and it did not produce as many flowers as the others.

Experiment five indicated that nitrogen toning produced plants with decreased leaf area and mass. Reducing the amount of nitrogen reduced the amount of vegetative growth in the plant but since the plant’s primary purpose is to complete its life cycle flowering was not affected for toning treatments of one to three weeks depending on the cultivar. In ‘Sundaze Bronze’, ‘Sundaze Pink’, and ‘Sundaze White’ there was little difference between two and three weeks of toning although flowering was decreased more with three weeks of toning. The high flower yield in relation to the high nitrogen concentrations are similar to the results found by Basappe (1980). He found the highest flower yield occurred with the highest nitrogen rate applied (150 kg/ ha). The number of buds decreased on plants toned for one week or more on ‘Sundaze Bronze’, ‘Sundaze Golden Beauty’ and ‘Sundaze Pink’. While decreasing the number of buds affects the number of flowers the plant will open after purchase, the total number of flowers on a plant was not affected by toning and the reduction in vegetative growth is desired for a healthy and affordable plant for both the grower and consumer.

In experiment eight, nitrogen toning caused more measurable effects on plant growth, flowering and quality than TDZ. However, there were TDZ effects on quality and leaf chlorosis. Overall the three cultivars reacted similarly to the treatments. Nitrogen toning prolonged the postharvest life of all three cultivars. By two weeks postharvest, the number of chlorotic leaves on the plants was unaffected by nitrogen toning for all cultivars. The SPAD readings indicated chlorophyll decreased as length of toning increased for all

three cultivars but TDZ application increased chlorophyll content on lower leaves of two cultivars. These readings agree with the postharvest counts of chlorotic leaves. The number of chlorotic leaves was reduced when TDZ was used with nitrogen toning but fertilization throughout production reduced the number of chlorotic leaves enough to negate the effect of TDZ on the number of chlorotic leaves. This promotes the use of TDZ if chlorotic leaves are a problem, but not if they are not excessive on the crop. In experiment four TDZ reduced the number of chlorotic leaves on cultivars that tended to have more chlorotic leaves naturally than those that have minimal chlorotic leaves.

One observation for all three cultivars was the plants that were fertilized throughout production appeared more susceptible to *Botrytis* attack. Within this treatment those that did not receive a TDZ spray were more susceptible than the other treatments. In ‘Sundaze White’ at the end of the postharvest treatment five of seven plants in this treatment combination died while for the other two TDZ treatments two plants died per treatment. Pavlista (2003) found that TDZ enhanced fungicidal activity in potatoes; he also found that TDZ alone delayed early blight by at least five days. Beno-Moualem et al. (2001) found TDZ seemed to enhance fungal resistance in avocado fruits. This fungicidal effect would be an added benefit to TDZ application, especially since this bracteantha series was susceptible to *Botrytis* attack when grown at close spacing on the greenhouse bench.

A visual effect of nitrogen toning was where flowers opened on the plant. Flowers opened within the canopy on plants that received fertilizer throughout production. Flowers opened above the canopy on plants that were toned. Whether this was due to decreased leaf production or peduncle elongation is unclear since height measurement was to the tallest point of the plant. Toning for two and three weeks did not change plant height from those

not toned in experiment five. In experiment eight, plant height was not affected by nitrogen toning for any cultivar. TDZ had little to no effect on flowering in any of the cultivars.

CHAPTER V

SUMMARY OF FINDINGS

- Common postharvest decline symptoms of nine genera of vegetative annuals were lower leaf chlorosis, flower abscission, and internode elongation.
- Shipping caused flower abscission in two genera, diascia and nemesia, both members of the Scrophulariaceae.
- Two days of shipping decreased postharvest quality of nine cultivars (43%) of the twenty one cultivars tested.
- Shipping for one day did not negatively affect postharvest quality of the twenty one cultivars tested.
- Nitrogen toning decreased plant width of bracteantha cultivars measured at harvest.
- Nitrogen toning affected number of flowers and/or quality rating of twenty one vegetative annual cultivars tested.
- Nitrogen toning for two or three weeks at the end of production decreased plant height, width and leaf area without reducing number of flowers on five cultivars of bracteantha.
- Thidiazuron (TDZ) at 2 or 5 μmol increased SPAD readings on lower leaves of two cultivars of bracteantha.

- When nitrogen toning caused lower leaf chlorosis, TDZ increased SPAD readings and green color of leaves.
- Two days of shipping increased flower abscission in one diascia cultivar.
- Shipping diascia cultivars at 24 °C decreased flower number and plant quality compared to shipping at 13 °C or 18 °C.
- There was a positive trend for the effect of 1-methylcyclopropene (1-MCP) on increasing postharvest performance of shipped diascia plants but results were inconsistent.
- Diascia that was not shipped had decreased flower abscission when treated with 1-MCP.
- A combination of four weeks of nitrogen toning at the end of production and TDZ foliar spray application to the lower leaves produced well proportioned bracteantha potted plants with reduced lower leaf chlorosis.
- Postharvest demise of bracteantha due to Botrytis infection was reduced with TDZ treatment.

LITERATURE CITED

- Armitage, A.M. 1993. Bedding plants: prolonging shelf performance, postproduction care and handling. Ball Publishing, Batavia, Ill.
- Banko, T.J. and M. Stefani. 1999. Defoliating deciduous hollies grown for the cut floral market. *Holly Soc. J.* 17(4):14-18.
- Basappa, H.S., A.A. Patil, V. Kanamadi, and Y.B. Patil. 1990. Effect of nitrogen and phosphorus on growth and yield of everlasting flower (*Helichrysum bracteatum* Andr.) cv. Tall Double Mixed. *South Indian Hort.* 38:211-214.
- Beno-Moualem, D., Y. Vinokur, and D. Prusky. 2001. Cytokinins increase epicatechin content and fungal decay resistance in avocado fruits. *J. Plant Growth Regul.* 20:95-100.
- Berghauer, E., J. Barrett and R. Schoellhorn. 2002. Taming the wild calibrachoa. *GPN.* 12(7):8-11.
- Blankenship, S.M. and J.M. Dole. 2003. 1-Methylcyclopropene: A review. *Postharvest Biol. Tech.* 28: 1-25.
- Brasswell, J.H., T.M. Blessington, and J.A. Price. 1982. Influence of cultural practices on postharvest interior performance of two species of schefflera. *HortScience* 17:345-347.
- Cameron, A.C. and M.S. Reid. 2001. 1-MCP blocks ethylene-induced petal abscission of *Pelargonium peltatum* but the effect is transient. *Postharvest Biol. Tech.* 22:169-177.

- Capelle, S.C., D.W.S. Mok, S.C. Kirchner, and M.C. Mok. 1983. Effects of thidiazuron on cytokinin autonomy and the metabolism of N⁶-(Δ^2 -isopentenyl)[8-¹⁴C]adenosine in callus tissues of *Phaseolus lunatus* L. Plant Physiol. 73:796-802.
- Çelikel, F.G., L.L. Dodge, and M.S. Reid. 2002. Efficacy of 1-MCP (1-methylcyclopropene) and Promalin for extending the postharvest life of Oriental lilies (*Lilium* x 'Mona Lisa' and 'Stargazer'). Sci. Hort. 93:149-155.
- Conover, C.A., L.N. Satterthwaite, and K.G. Steinkamp. 1993. Production fertilizer and postharvest light intensity effects on begonias. Proc. Fla. State Hort. Soc. 106:299-302.
- D'hont, K., J. Langeslag, and B.L. Dahlhaus. 1991. The effect of different growth regulators and chemical treatments used during postharvest for preserving quality of chrysanthemums. Acta Hort. 298:211-214.
- Dole, J.M. and H.F. Wilkins. 1999. Floriculture principles and species. Prentice Hall, Upper Saddle River, NJ.
- Druege, U. 2001. Postharvest responses of different ornamental products to preharvest nitrogen supply: Role of carbohydrates, photosynthesis and plant hormones. Acta Hort. 542:97-105.
- Ferrante, A., D.A. Hunter, W.P. Hackett, and M.S. Reid. 2002. Thidiazuron – a potent inhibitor of leaf senescence in *Alstromeria*. Postharv. Bio. Technol. 25:333-338.
- Ferrante A., A. Mensuali-Sodi, G. Serra, and F. Tognoni. 2002. Effects of ethylene and cytokinins on vase life of cut *Eucalyptus parvifolia* Cabbage branches. Plant Growth Regulat. 38:119-125.

- Ferrante, A., F. Tognoni, A. Mensuali-Sodi, and G. Serra. 2003. Treatment with thidiazuron for preventing leaf chlorosis in cut tulips and chrysanthemum. *Acta Hort.* 624: 357-363.
- Harris, D.R., J.A. Seberry, R.B.H. Wills, and L.J. Spohr. Effect of fruit maturity on efficiency of 1-methylcyclopropene to delay the ripening of bananas. *Postharvest Biol. Tech.* 20:303-308.
- Hendriks, L. 2001. Cultural factors affecting post-harvest quality of potted plants. *Acta Hort.* 543:87-96.
- Henne, L. 2002. Varieties: A renaissance. *Greenhouse Grower* 20(14):6-7.
- Hoyer, L. 1995. Investigations of the ethylene build-up during transport of pot plants in controlled temperature trucks. *Postharvest Biol. Tech.* 5:101-108.
- Kelly, J.W. and T.W. Starman. 1990. Postharvest handling of *Physostegia purpurea* cut flowers. *HortScience* 25:552-553.
- King, A., M. Yi, A. Ferrante, and M.S. Reid. 2001. Thidiazuron reduces leaf senescence and abscission in flowering potted plants. *HortScience* 36:599 (abstr.).
- Macz, O., E.T. Paparozzi, W.W. Stroup, R. Leonard, and T.A. Nell. 2001. Effect of nitrogen and sulfur applications on pot chrysanthemum production and postharvest performance. II. plant growth responses. *J. Plant Nut.* 24: 131-146.
- Matsoukis, A.S., A. Chronopoulou-Sereli, I.D. Dimopoulos, and A. Kamoutsis. 2001. Response of *Lantana camara* L. subsp. *camara* to paclobutrazol and shading. *Can. J. Plant. Sci.* 81:761-764.

- Miller, S.H. and R.D. Heins. 1986. Variation in cyathia abscission of poinsettia cultivars in a greenhouse and a simulated postharvest environment. *HortScience* 21:270-272.
- Miller, W.B., P.A. Hammer, and T.I. Kirk. 1993. Reversed greenhouse temperatures alter carbohydrate status in *Lilium longiflorum* Thunb. 'Nellie White'. *J. Amer. Soc. Hort. Sci.* 118:736-740.
- Moe, R., T. Fjeld, and L.M. Mortensen. 1992. Stem elongation and keeping quality in poinsettia (*Euphorbia pulcherrima* Willd.) as affected by temperature and supplementary lighting. *Sci. Hort.* 50:127-136.
- Muller, R., E.C. Sisler, and M. Serek. 2000. Stress induced ethylene production, ethylene binding, and the response to the ethylene action inhibitor 1-MCP in miniature roses. *Sci. Hort.* 83:51-59.
- Mueller, R., A.S. Andersen, M. Serek, and B.M. Stummann, 2001. Physiological and genetic reasons for different postharvest characteristics in miniature potted roses. *Acta Hort.* 543:153-159.
- Nell, T.A. and J.E. Barrett. 1986b. Growth and incidence of bract necrosis in 'Gutbier V-14 Glory' poinsettias. *J. Amer. Soc. Hort. Sci.* 111:266-269.
- Nell, T.A. and J.E. Barrett. 1986a. Influence of simulated shipping on the interior performance of poinsettias. *HortScience* 21:310-312.
- Nell, T.A. and L. Hoyer. 1995. Terminology and conditions for evaluation of flowering potted plant longevity. *Acta Hort.* 405:28-32.

- Nell, T.A., J.E. Barrett, and R.T. Leonard. 1989. Fertilization termination influences postharvest performance of pot chrysanthemum. *HortScience* 24:996-998.
- Nell, T.A., R.T. Leonard, and J.E. Barrett. 1995. Production factors affect the postproduction performance of poinsettia – a review. *Acta Hort.* 405: 132-137.
- Nell, T.A. and C.V. Noordegraaf. 1991. Simulated transport, postproduction irradiance influence postproduction performance of potted roses. *HortScience* 26(11):1401-1404.
- Nell, T.A., J.J. Allen, J.N. Joiner, and L.G. Albrigo. 1981. Light, fertilizer, and water level effects on growth, yield, nutrient composition, and light compensation point of chrysanthemum. *HortScience* 16: 222-223.
- Nell, T.A., R.T. Leonard, A.A. De Hertogh, and J.E. Barrett. 1995. Postproduction evaluations of potted Asiatic and oriental hybrid lilies. *HortScience* 30(7):1433-1435.
- Nelson, P.V. 1998. Greenhouse operation and management. 5th ed. Simon and Schuster, Upper Saddle River, N.J.
- Noordegraaf, C.V. 1995. How to obtain and maintain quality. *Acta Hort.* 405:123-131.
- Pavlista, A. 2003. Thidiazuron, a cytokinin-like compound, enhances fungicidal activity against early blight in potato. *Acta Hort.* 619:145-152.
- Ranwala, A.P., W.B. Miller, T.I. Kirk, and P.A. Hammer. 2000. Ancymidol drenches, reversed greenhouse temperatures, postgreenhouse cold storage, and hormone sprays affect postharvest leaf chlorosis in Easter lily. *J. Amer. Hort. Sci.* 125:248-253.
- Risse, L.A., R.E. McDonald, and A.J. Bongers. 1989. Control of temperature and relative humidity in van containers of potted areca palms in export shipments to Europe. *Proc. Fla. State Hort. Soc.* 102:164-166.

- Roude, N., T.A. Nell, and J. E. Barrett. 1991. Nitrogen source and concentration, growing medium, and cultivar affect longevity of potted chrysanthemums. *HortScience* 26:49-52.
- Sankhala, N., W.A. Mackay, and T.D. Davis. 2001. Extension of vase life and prevention of ethylene-induced flower shattering in *Lupinus havardii* by 1-methylcyclopropene. *Acta Hort.* 543:75-78.
- Serek, M. 1990. Effects of pre-harvest fertilization on the flower longevity of potted *Campanula carpatica* 'Karl Foerster'. *Sci. Hort.* 44:119-126.
- Serek, M. and M.S. Reid. 2000. Ethylene and postharvest performance of potted kalanchoe. *Postharvest Biol. Tech.* 18:43-48.
- Serek, M. and E.C. Sisler. 2001. Efficacy of inhibitors of ethylene binding in improvement of the postharvest characteristics of potted flowering plants. *Postharvest Biol. Tech.* 23:161-166.
- Serek, M., E.C. Sisler, and M.S. Reid. 1994. Novel gaseous ethylene binding inhibitor prevents ethylene effects in potted flowering plants. *J. Amer. Soc. Hort. Sci.* 119:123-1233.
- Serek, M., E.C. Sisler, and M.S. Reid. 1995. Effects of 1-MCP on the vase life and ethylene response of cut flowers. *Plant Growth Regulat.* 16:93-97.
- Serek, M., A. Prabucki, E.C. Sisler, and A.S. Andersen. 1998. Inhibitors of ethylene action affect final quality and rooting of cuttings before and after storage. *HortScience* 33: 153-155.

- Sherman, K.V., M. Sedgley, and D. Apinall. 1989. Effects of photoperiod, temperature and plant age on floral initiation and inflorescence quality in the Australian native daisies *Helipterum roseum* and *Helichrysum bracteatum* in relation to cut-flower production. J. Hort. Sci. 64:351-359.
- Sisler, E.C. and M. Serek. 1997. Inhibitors of ethylene responses in plants at the receptor level: Recent developments. Physiol. Plant. 100:577-582.
- Snipes, C.E. and G.W. Cathey. 1992. Evaluation of defoliant mixtures in cotton. Field Crop Res. 28:327-334.
- ter Hell, B. and L. Hendriks. 1995. The influence of nitrogen nutrition on keeping quality of pot plants. Acta Hort. 405:138-147.
- Thaxton, D.R., J.W. Kelly, and J.J. Frett. 1988. Control of *Hibiscus rosa-sinensis* L. bud abscission during shipping. Sci. Hort. 34:131-137.
- Thomas, J.C. and F.R. Katterman. 1986. Cytokinin activity induced by thidiazuron. Plant Physiol. 81:681-683.
- Tjosvold, S.A., M.J. Wu, and M.S. Reid. 1995. Reduction of post-production quality loss in potted miniature roses. Acta Hort. 405:408-414.
- van Doorn, W.G. and E.J. Woltering. 1991. Developments in the use of growth regulators for the maintenance of post-harvest quality in cut flowers and potted plants. Acta Hort. 298:195-209.
- van Meeteren, U. and h. van Gelder. 1995. Role of flower bud abscission in hibiscus. Acta Hort. 405: 284-289.

Veen, H. 1983. Silver thiosulphate: An experimental tool in plant science. *Sci. Hort.* 20: 211-224.

Williams, M.H., E. Rosenqvist, and M. Buchhave. 2000. The effect of reducing production water availability on the post-production quality of potted miniature roses (*Rosa ×hybrida*). *Postharvest Biol. Tech.* 18:143-150.

Willumsen, K. and T. Fjeld. 1995. The sensitivity [sic] of some flowering potted plants to exogenous ethylene. *Acta Hort.* 405:362-371.

Woltering, E.J. 1985. Sensitivity of various foliage and flowering potted plants to ethylene. *Acta Hort.* 181:489-492.

Woltering, E.J. 1987. Effects of ethylene on ornamental pot plants: A classification. *Sci. Hort.* 31:283-294.

Woltering, E.J. and W.G. Van Doorne, 1988. Role of ethylene in senescence of petals – morphological and taxonomical relationships. *J. Expt. Bot.* 39: 1605-1616.

Woodson, W.R. and M.L. Jones. 2003. In search of eternal youth: The delay of postharvest senescence in flowers. *Acta Hort.* 624:305-314.

APPENDIX A**TEMPERATURE AND LIGHT GRAPHS**

Fig. A-1. Average day and night temperatures and total daily light levels in the greenhouse at canopy level Spring 2003 (Expts. 1,2, and 3).

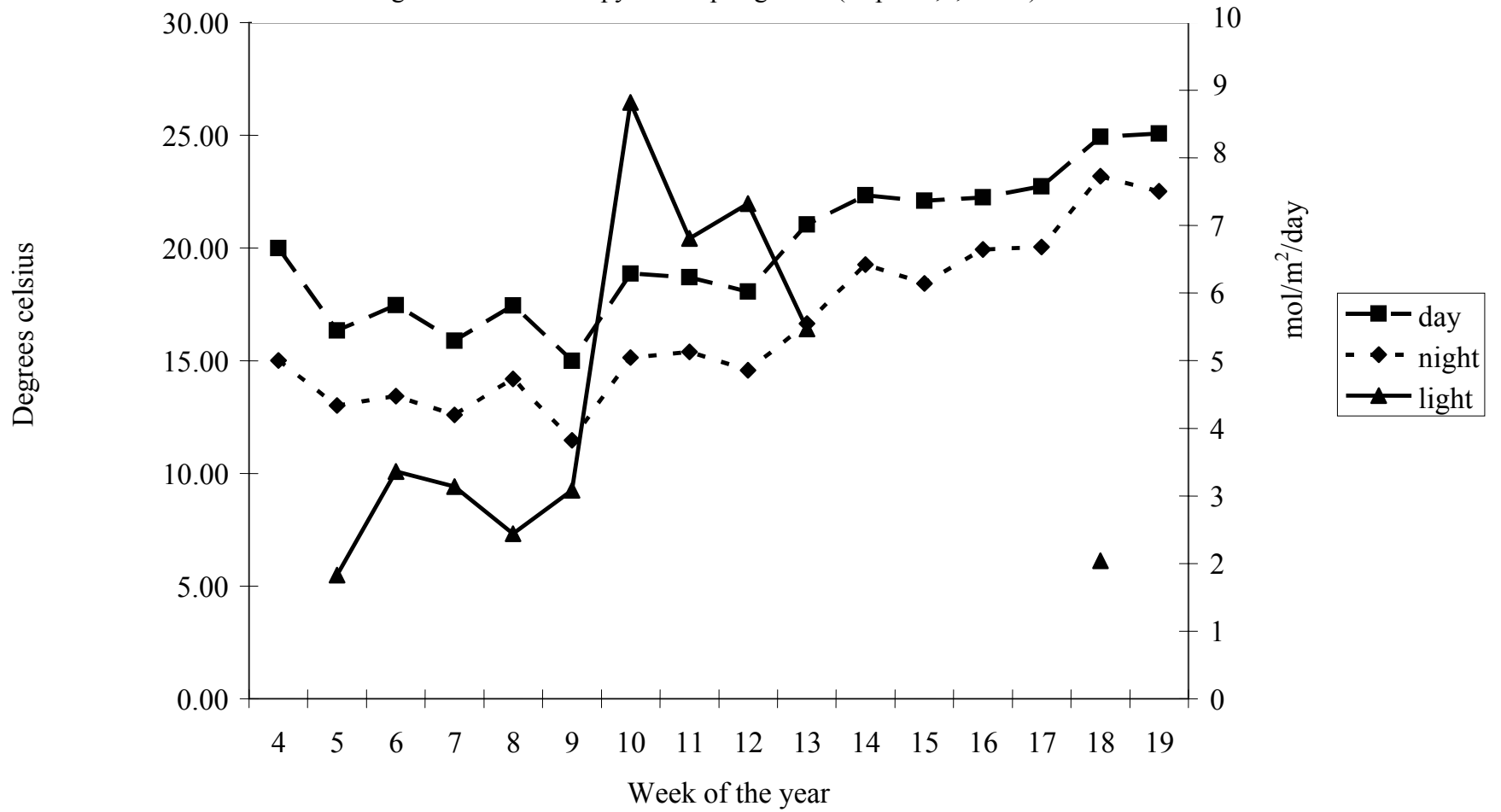


Fig. A-2. Average day and night temperatures and total daily light levels in the greenhouse at canopy level Summer 2003 (Expts. 4 and 5).

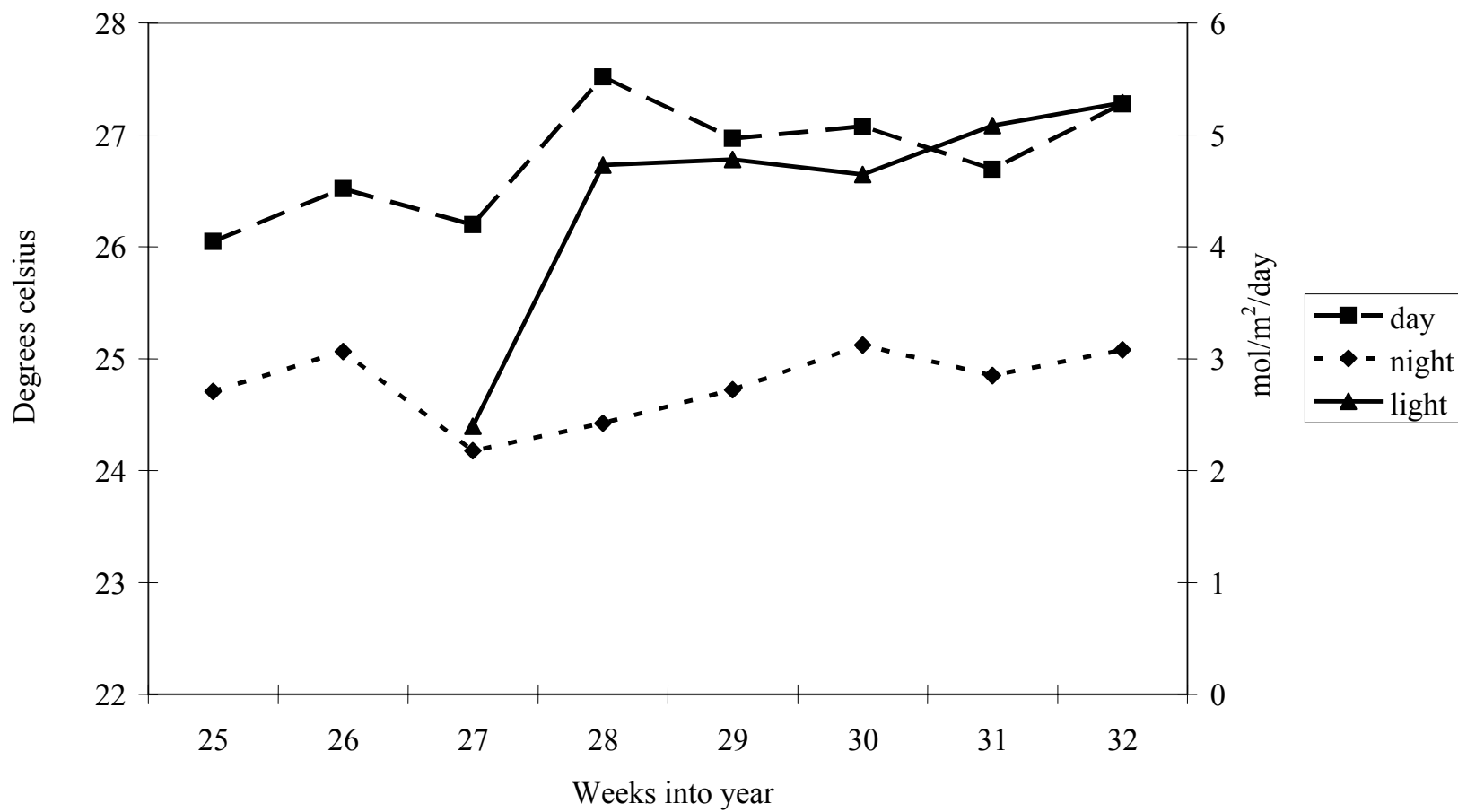


Fig. A-3. Average day and night temperatures and total daily light levels in the greenhouse at canopy level Fall 2003 (expt. 6).

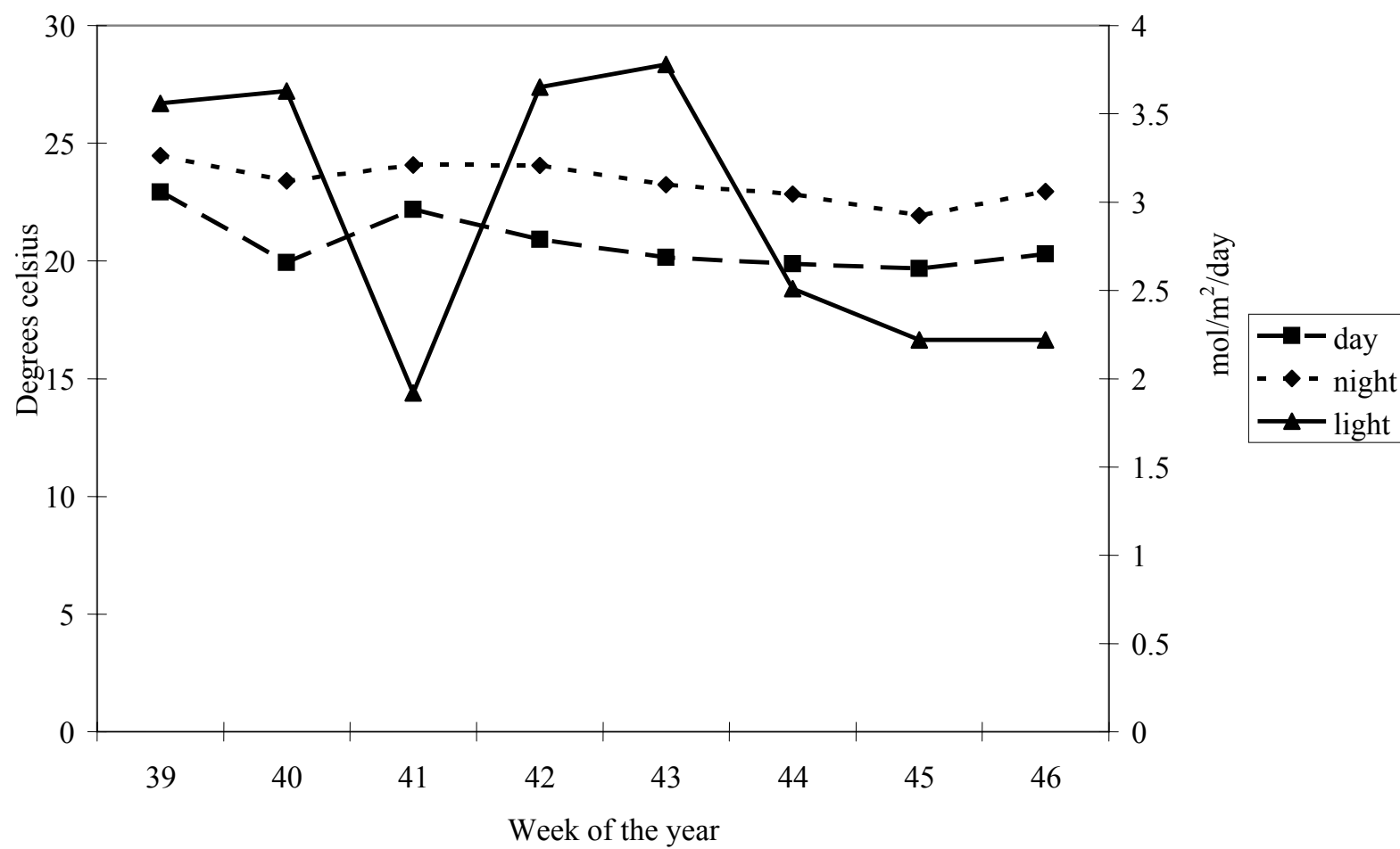


Fig. A-4. Average day and night temperatures and total daily light levels in the greenhouse at canopy level Spring 2004 (Expt. 7).

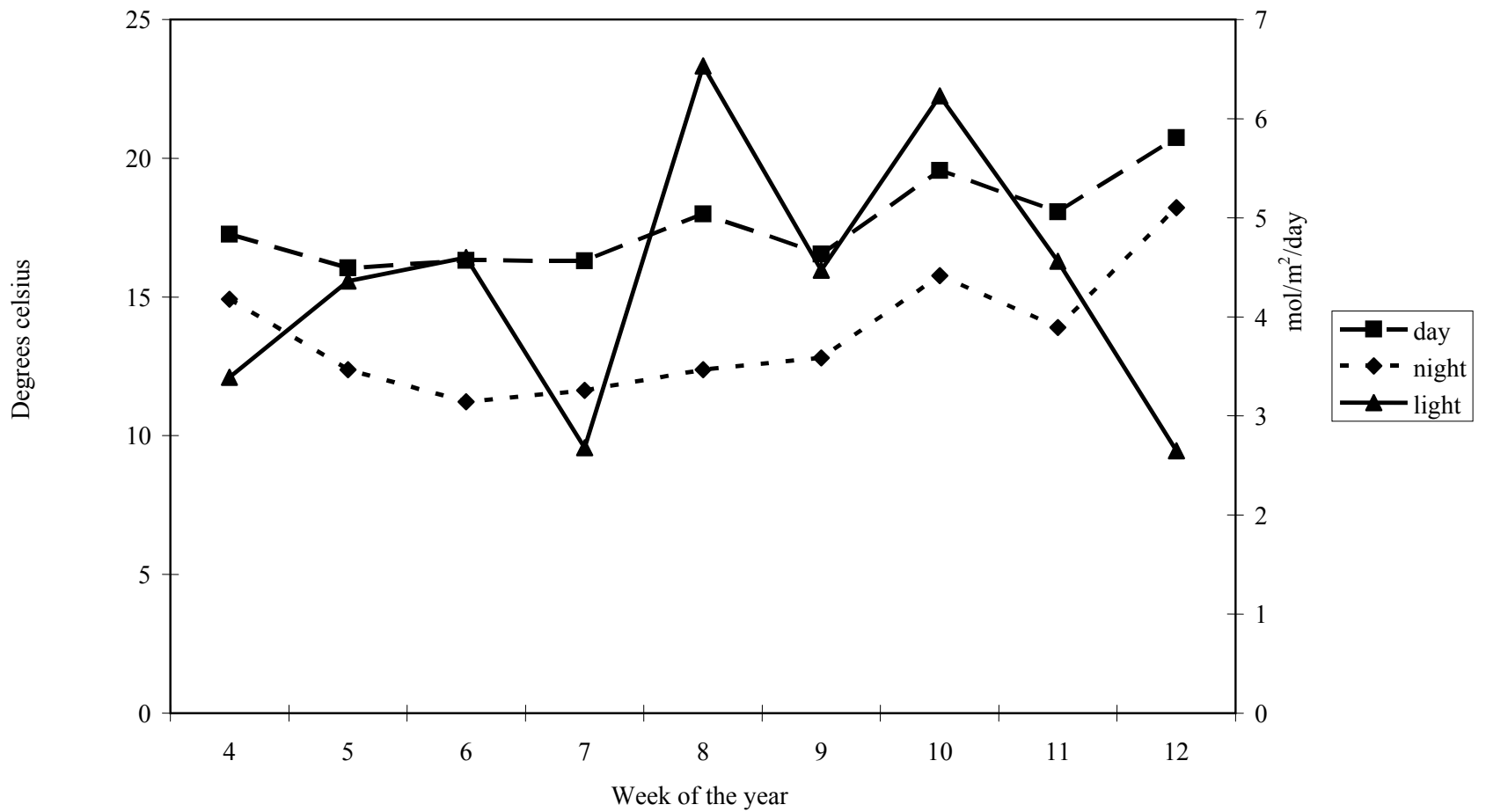


Fig. A-5. Average weekly day and night temperatures and total daily light levels in the greenhouse at canopy level Spring 2004 (Expt. 8).

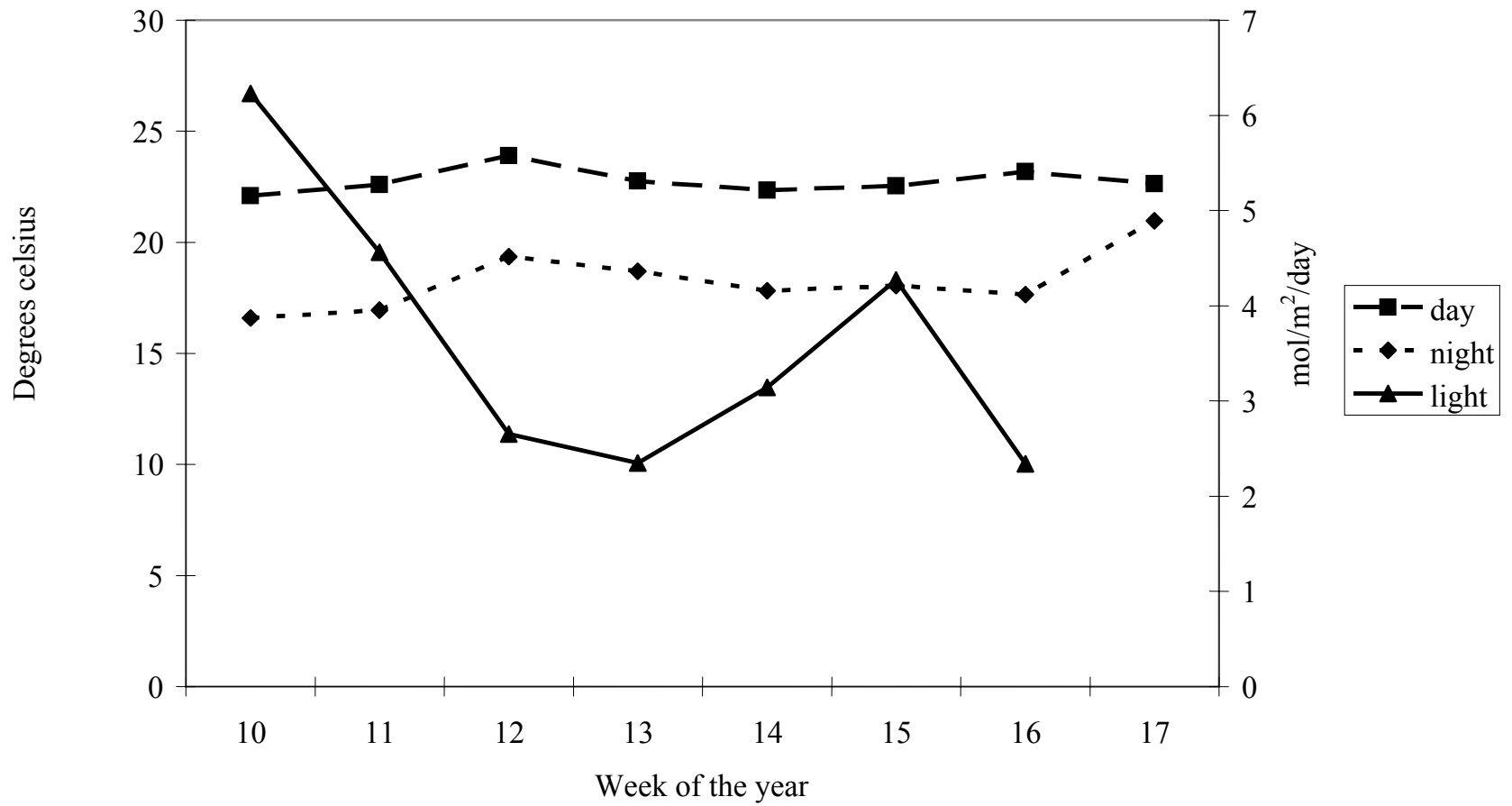


Fig. A-6. Average simulated shipping temperature Spring 2003 (Expt. 1).

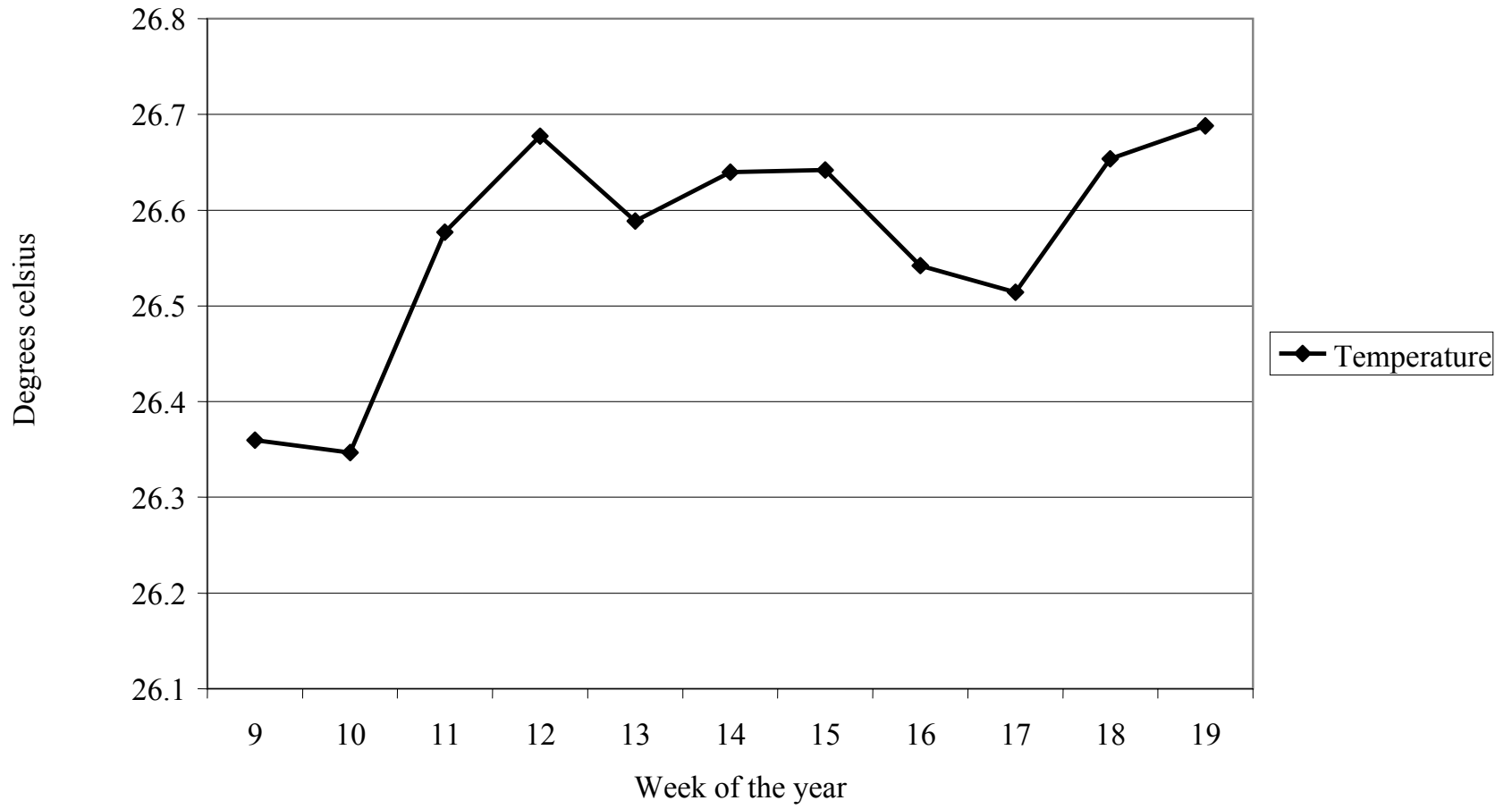


Fig. A-7. Average shipping temperatures Spring 2004 (Expt.7).

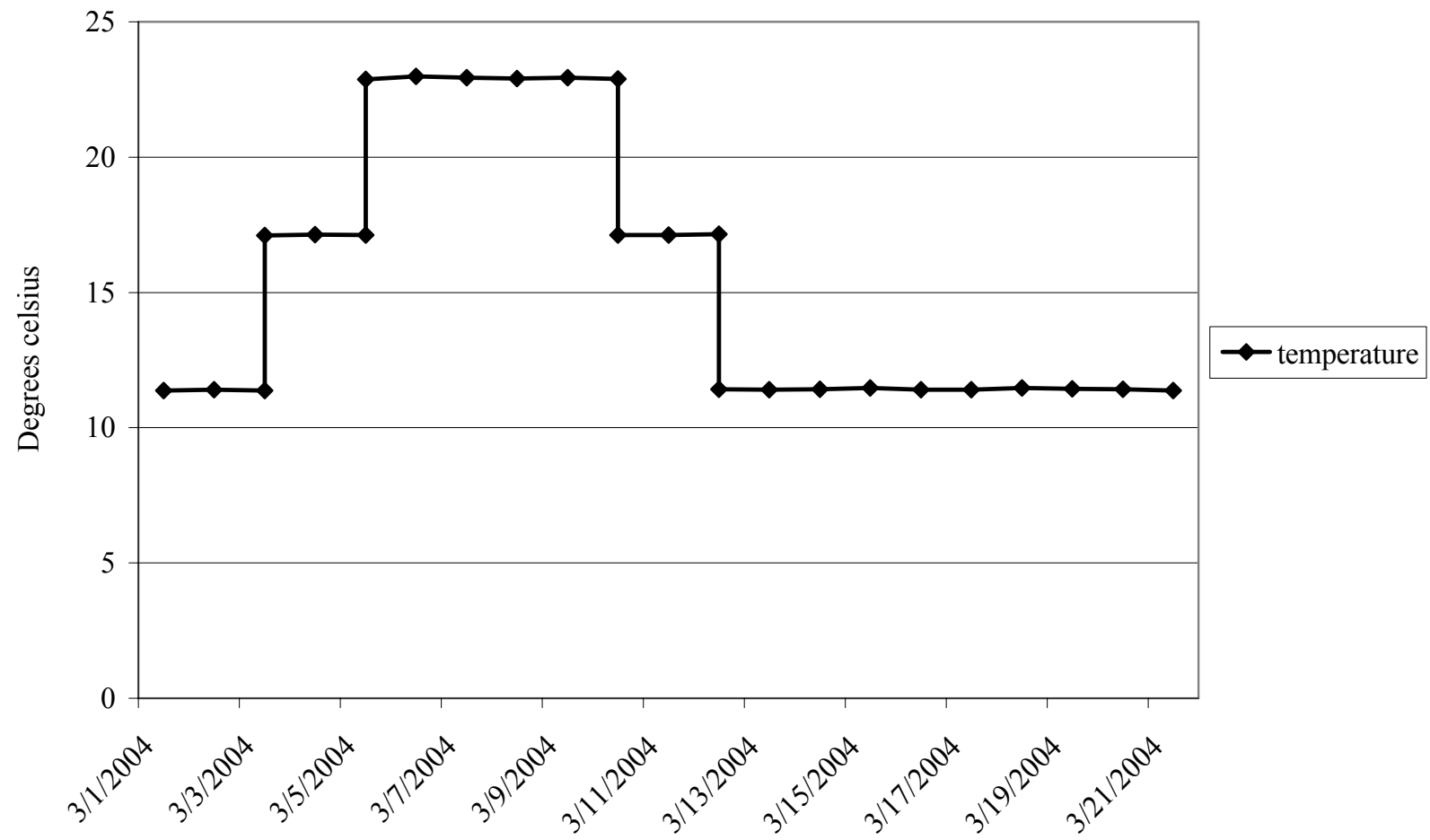


Fig. A-8. Average growth room temperature Spring 2003 (Expts. 1, 2, and 3).

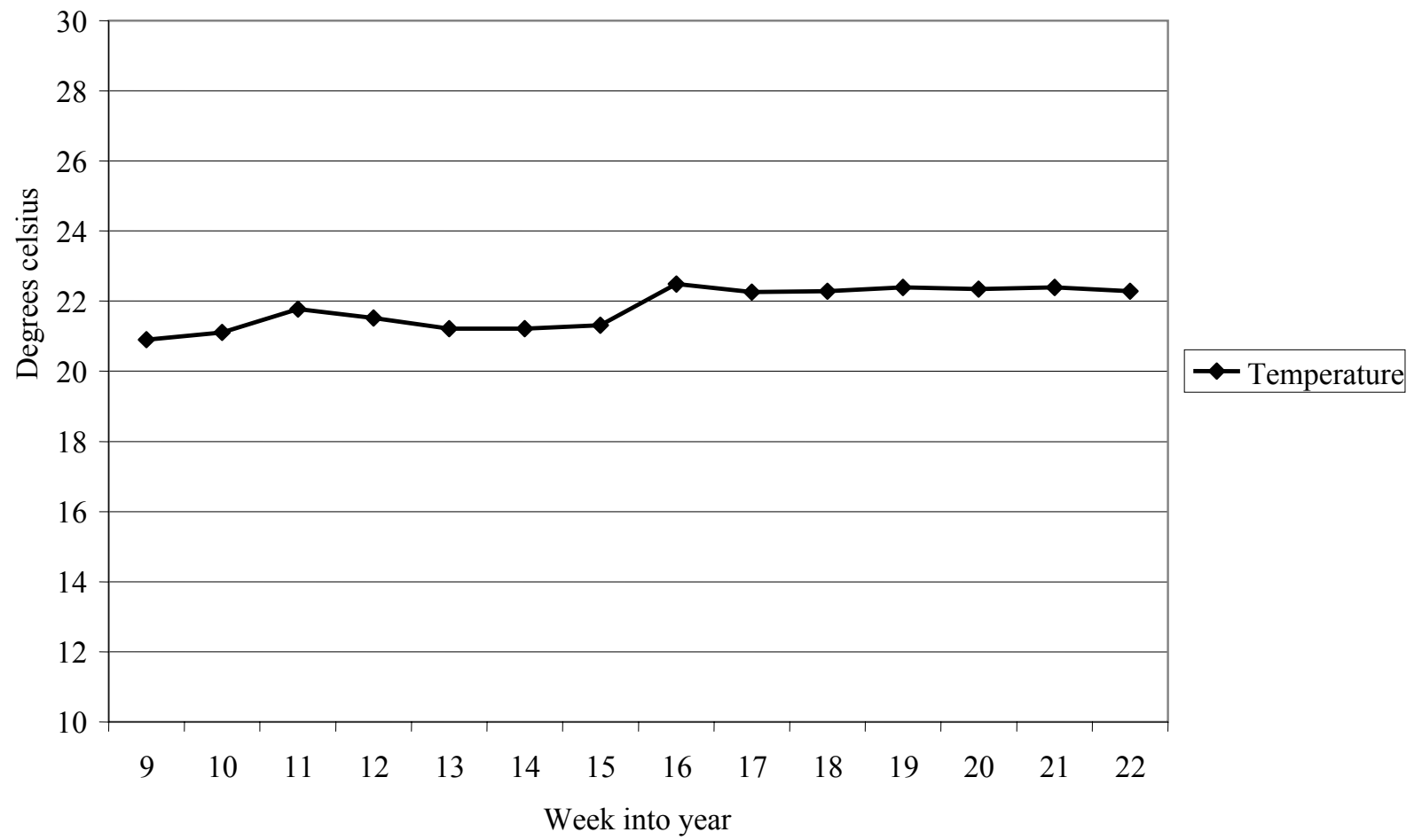


Fig. A-9. Growth room temperatures Fall 2003 (Expt. 6).

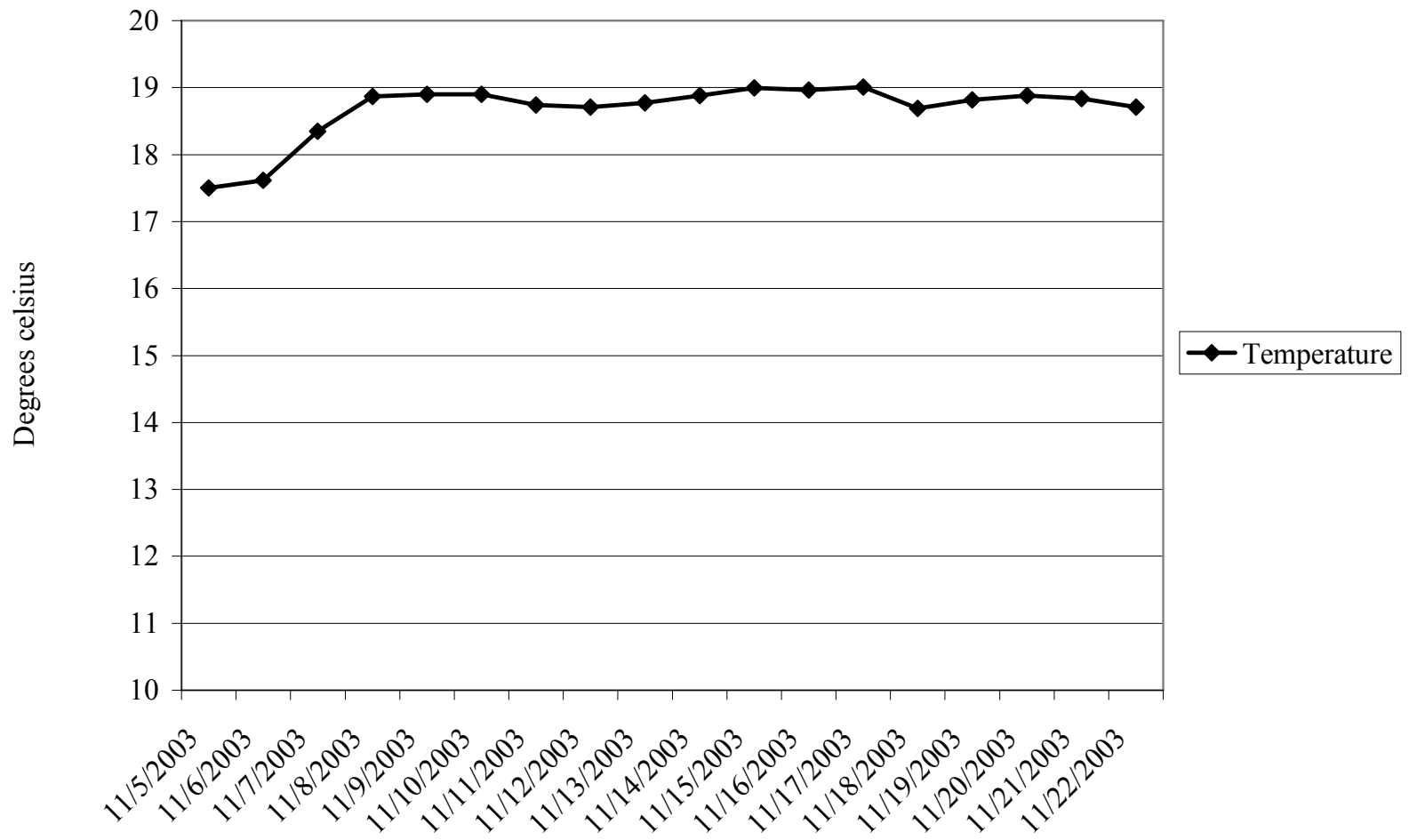
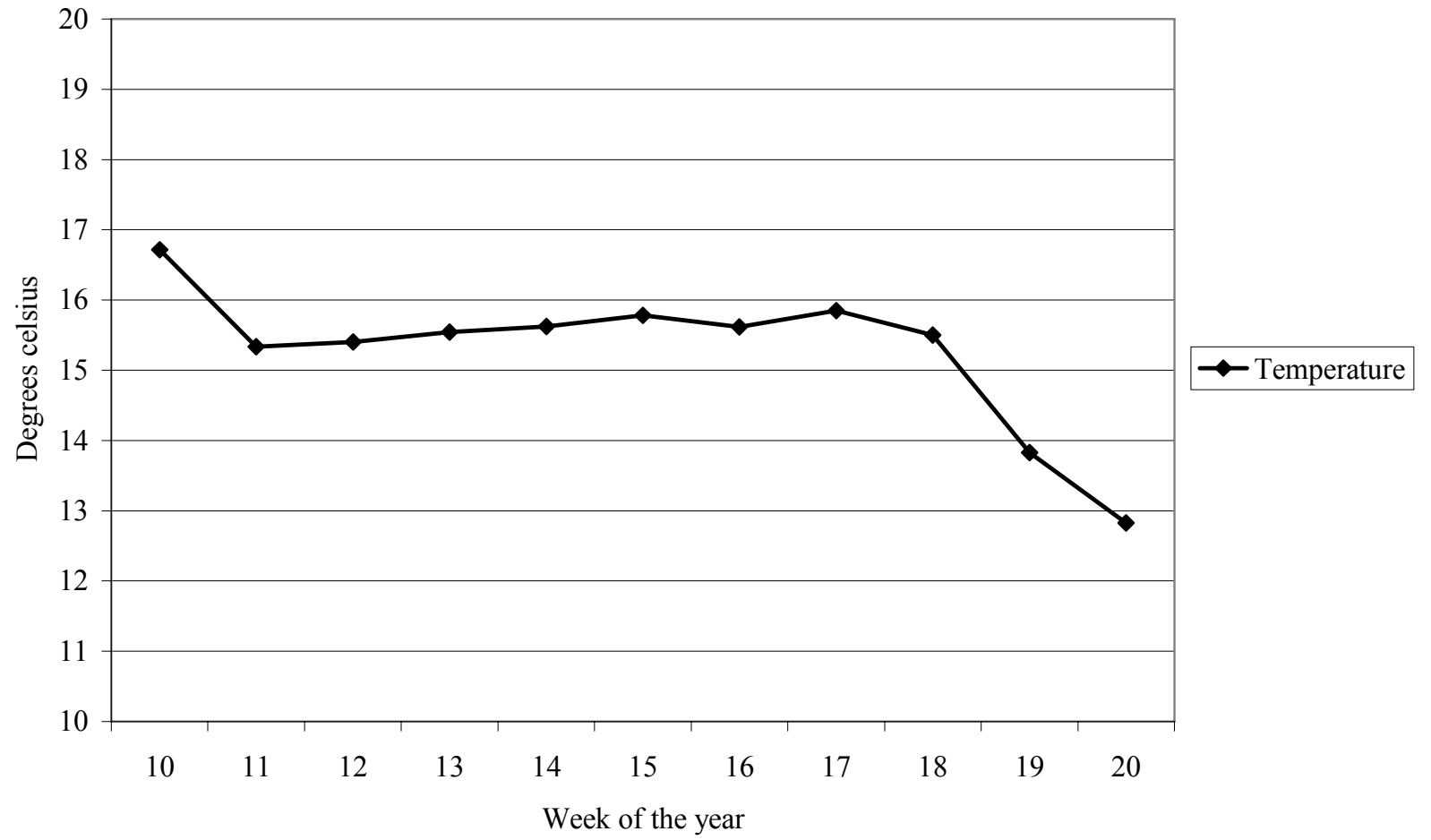


Fig. A-10. Growth room temperatures Spring 2004 (Expts. 7 and 8).



APPENDIX B**WEEKLY AVERAGE EC AND pH CHARTS FROM EXPERIMENT 5**

Fig. B-1. Effect of nitrogen toning on weekly average EC values on *Bracteantha bracteata* 'Sundaze Bronze'.

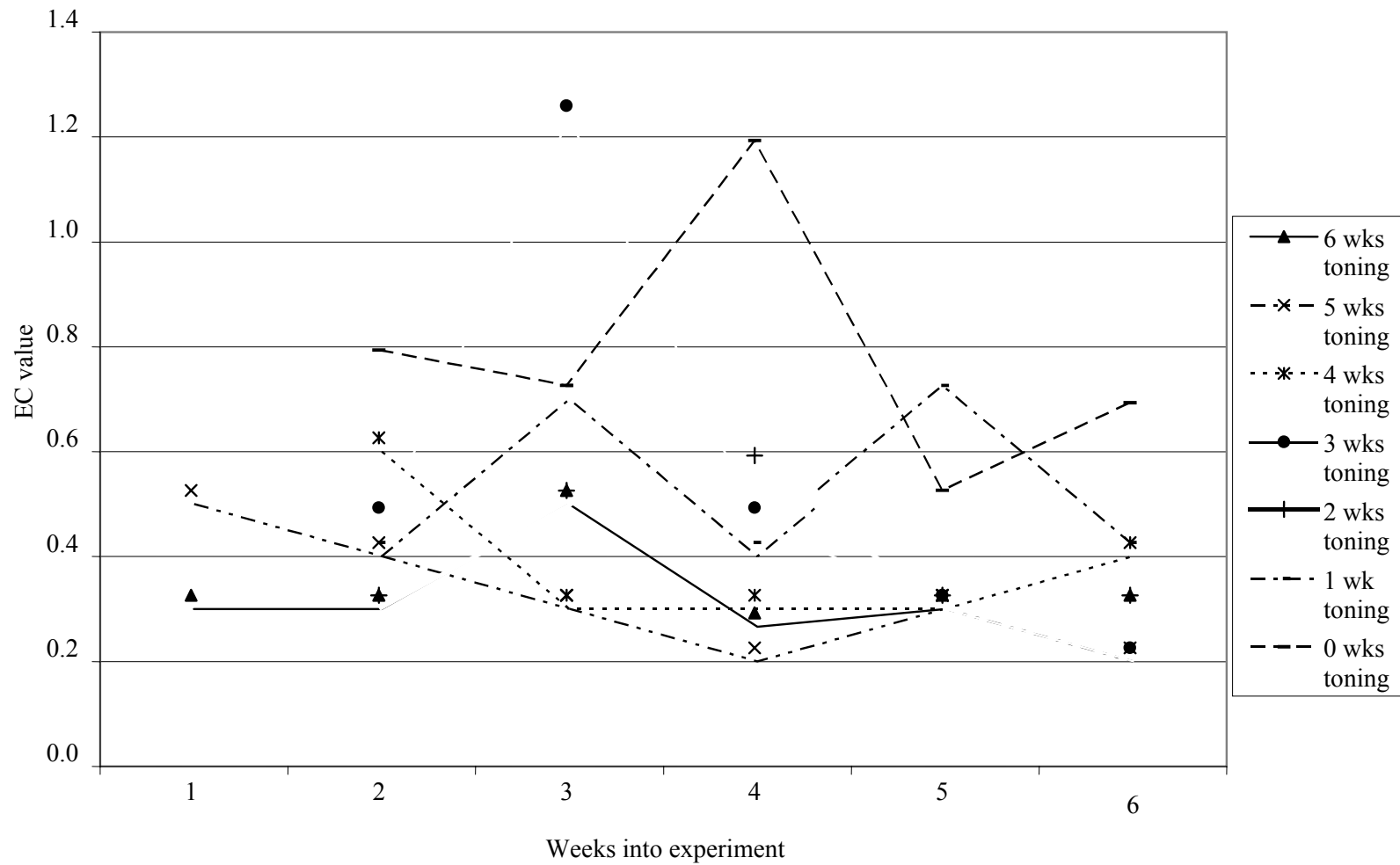


Fig. B-2. Effect of nitrogen toning on weekly average EC values on *Bracteantha bracteata* 'Sundaze Golden

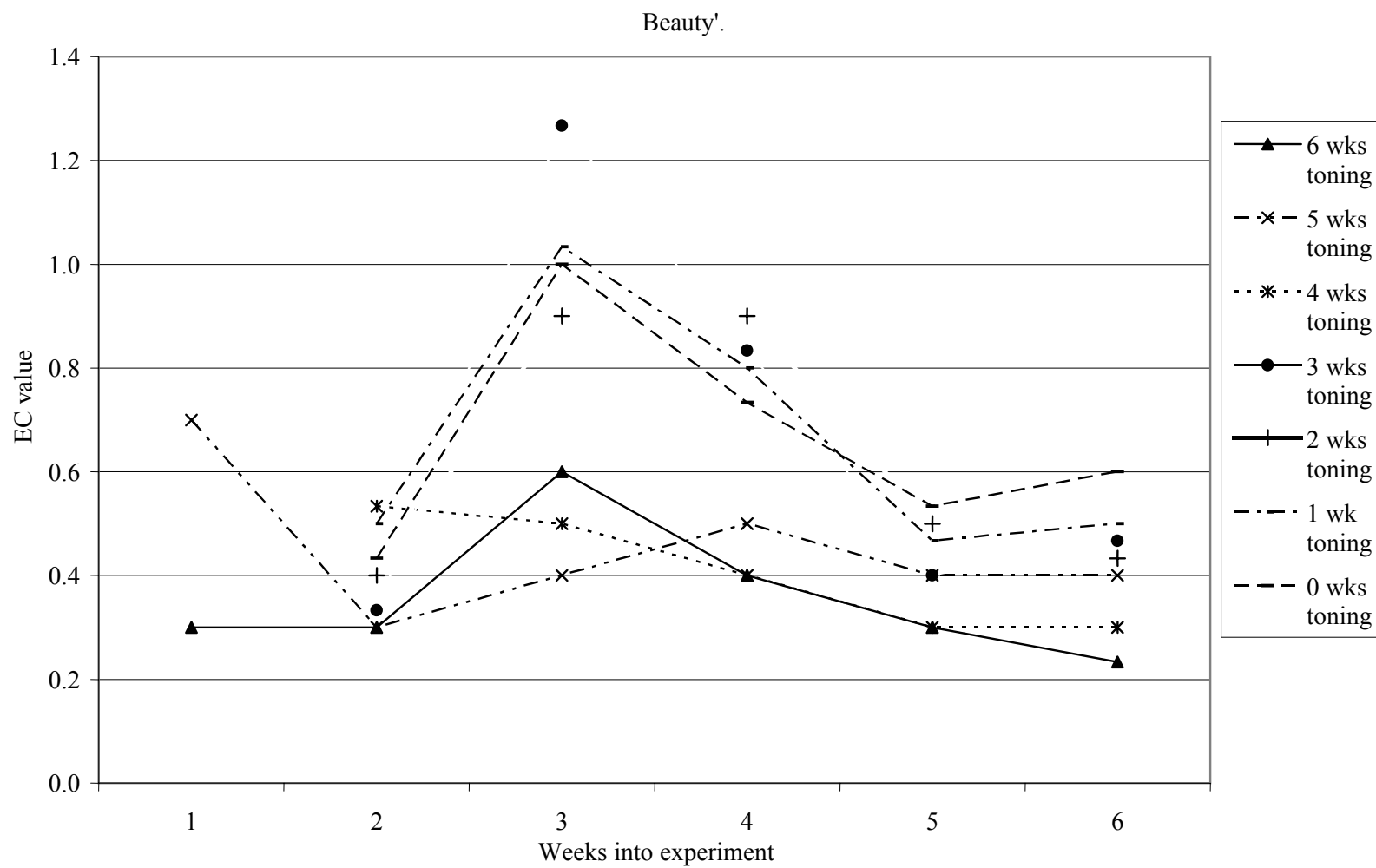


Fig. B-3. Effect of nitrogen toning on weekly average EC values of *Bracteantha bracteata* 'Sundaze Golden

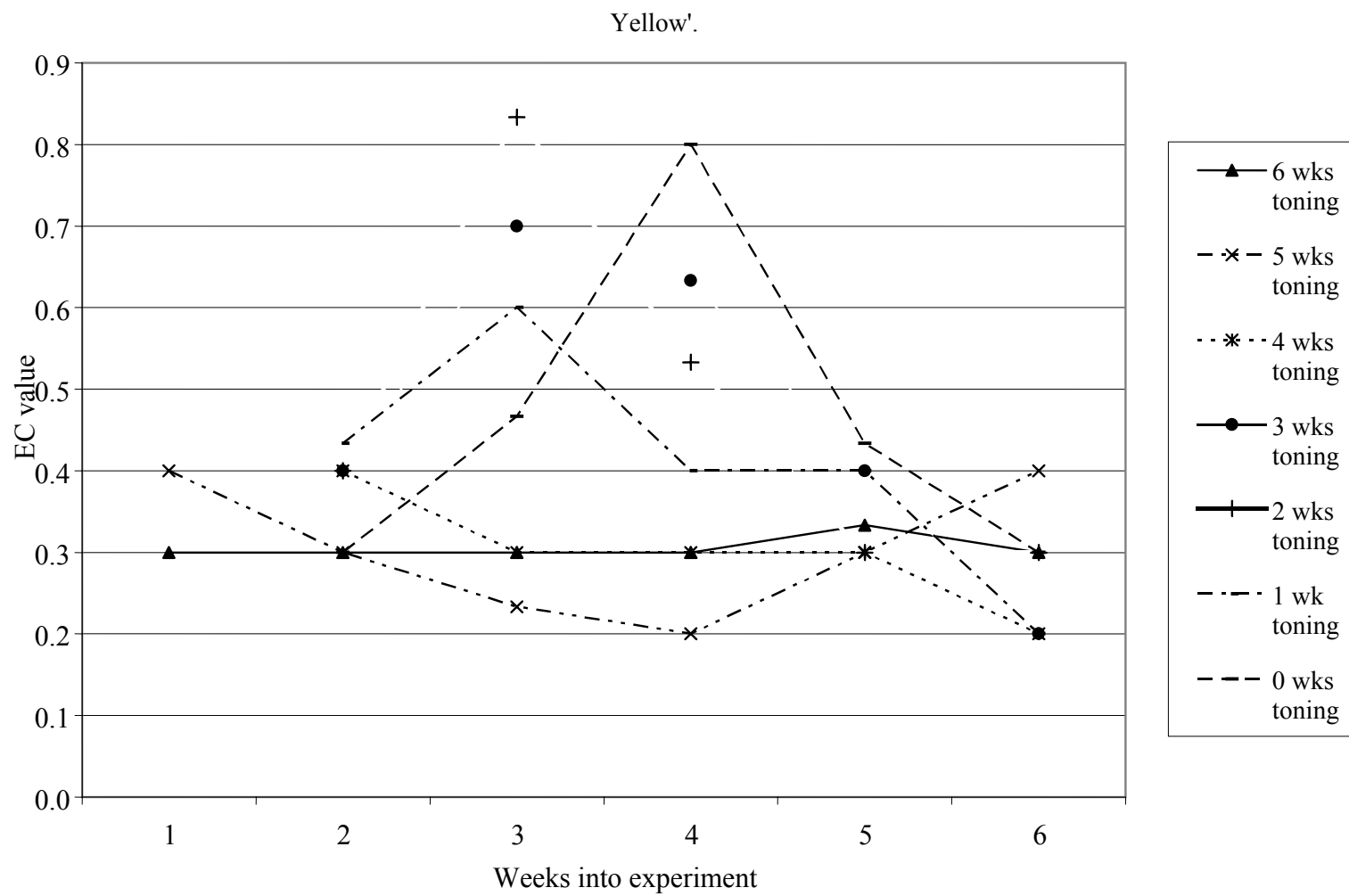


Fig. B-4. Effect of nitrogen toning on weekly average EC values on *Bracteantha bracteata* 'Sundaze Pink'.

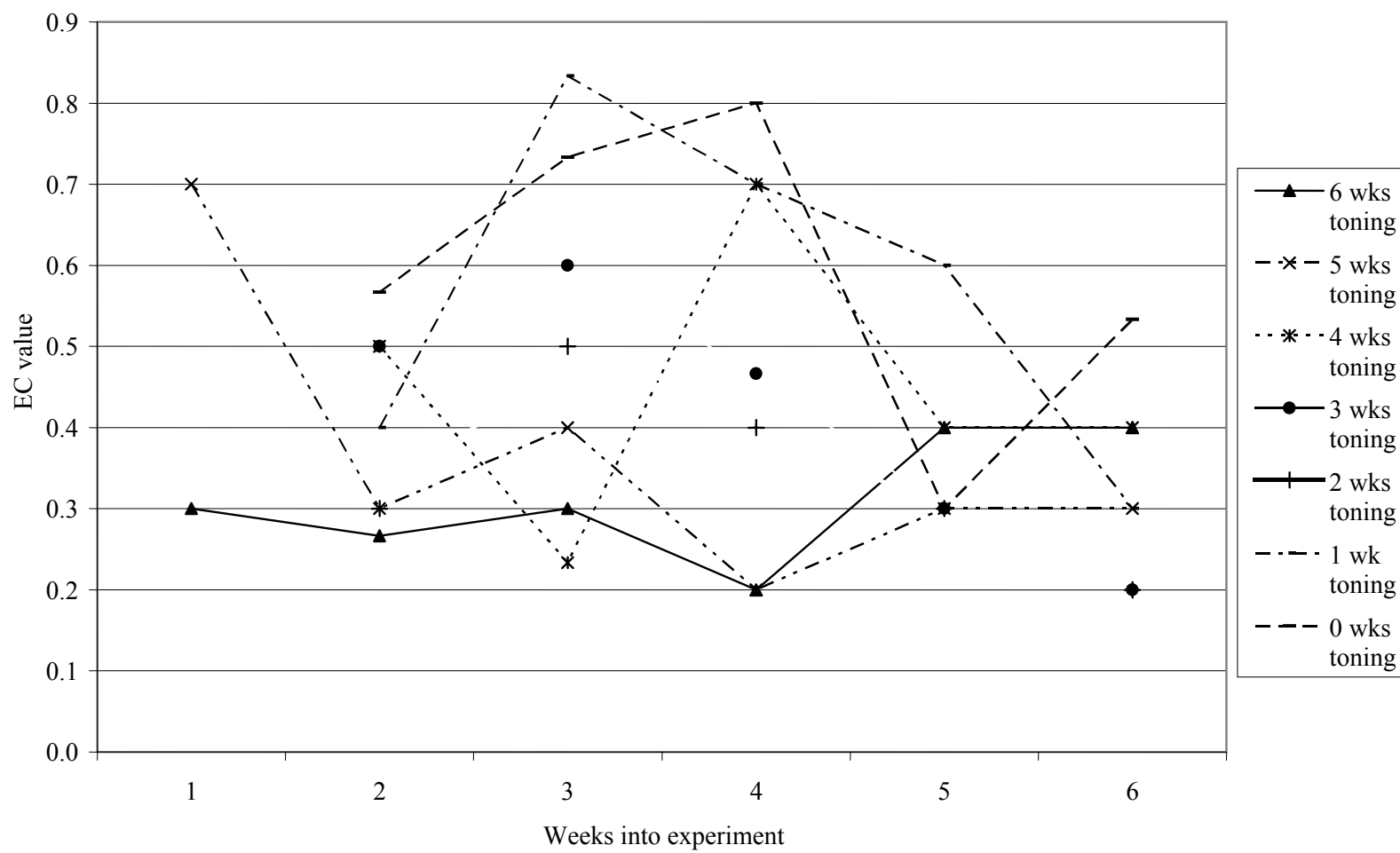


Fig. B-5. Effect of nitrogen toning on weekly average EC values on *Bracteantha bracteata* 'Sundaze White'.

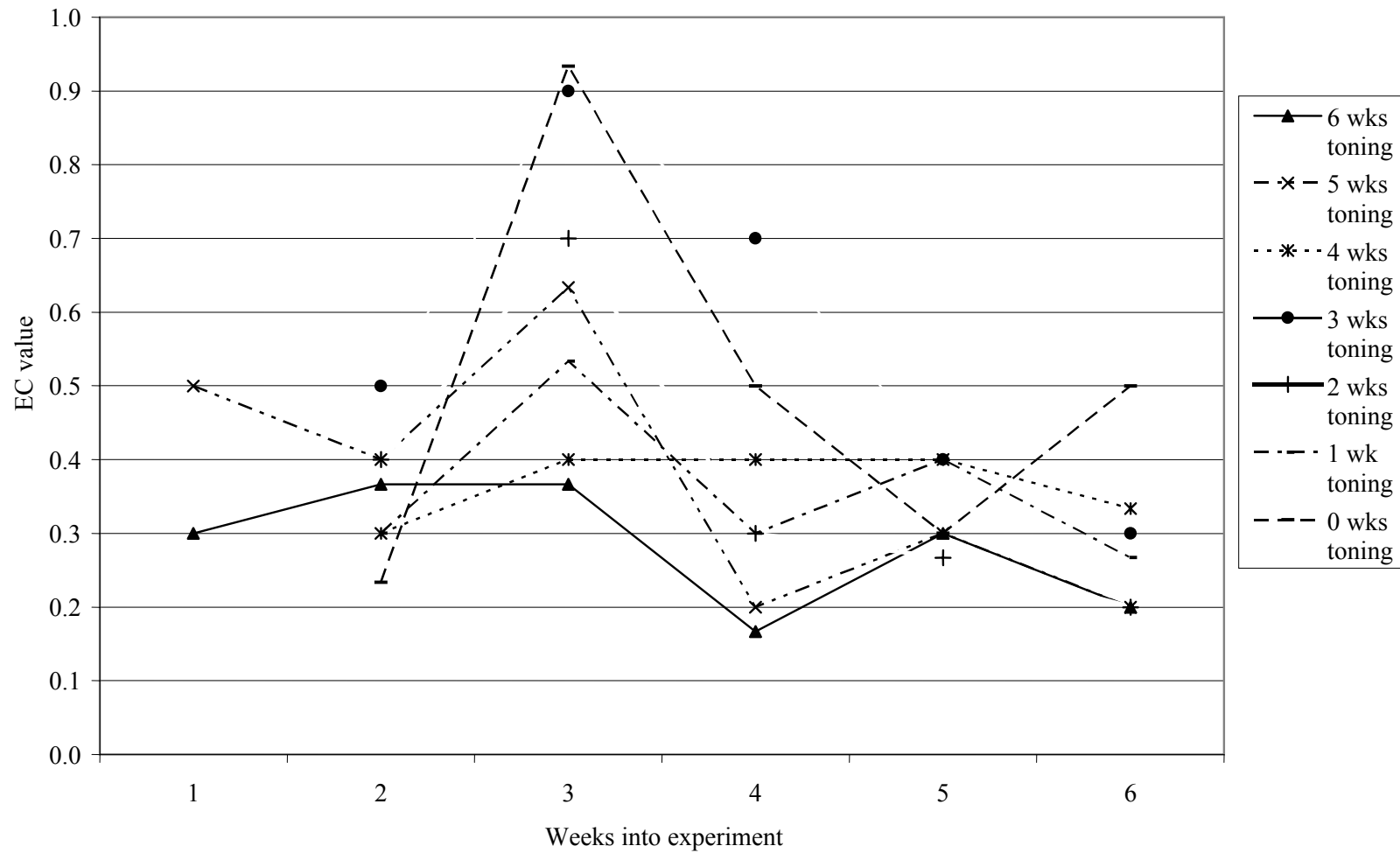


Fig. B-6. Effect of nitrogen toning on weekly average pH values on *Bracteantha bracteata* 'Sundaze Bronze'.

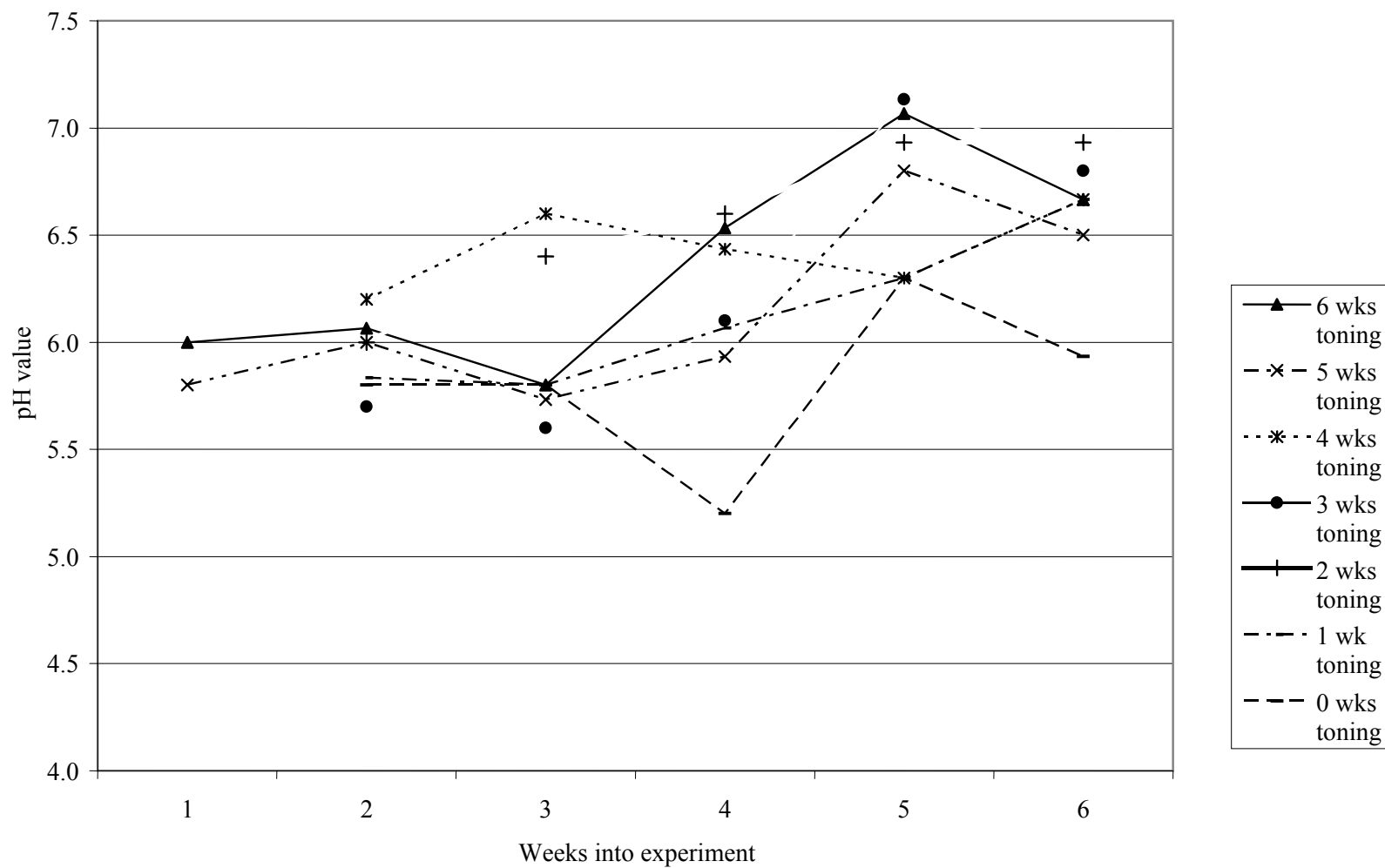


Fig. B-7. Effect of nitrogen toning on weekly average pH values on *Bracteantha bracteata* 'Sundaze Golden

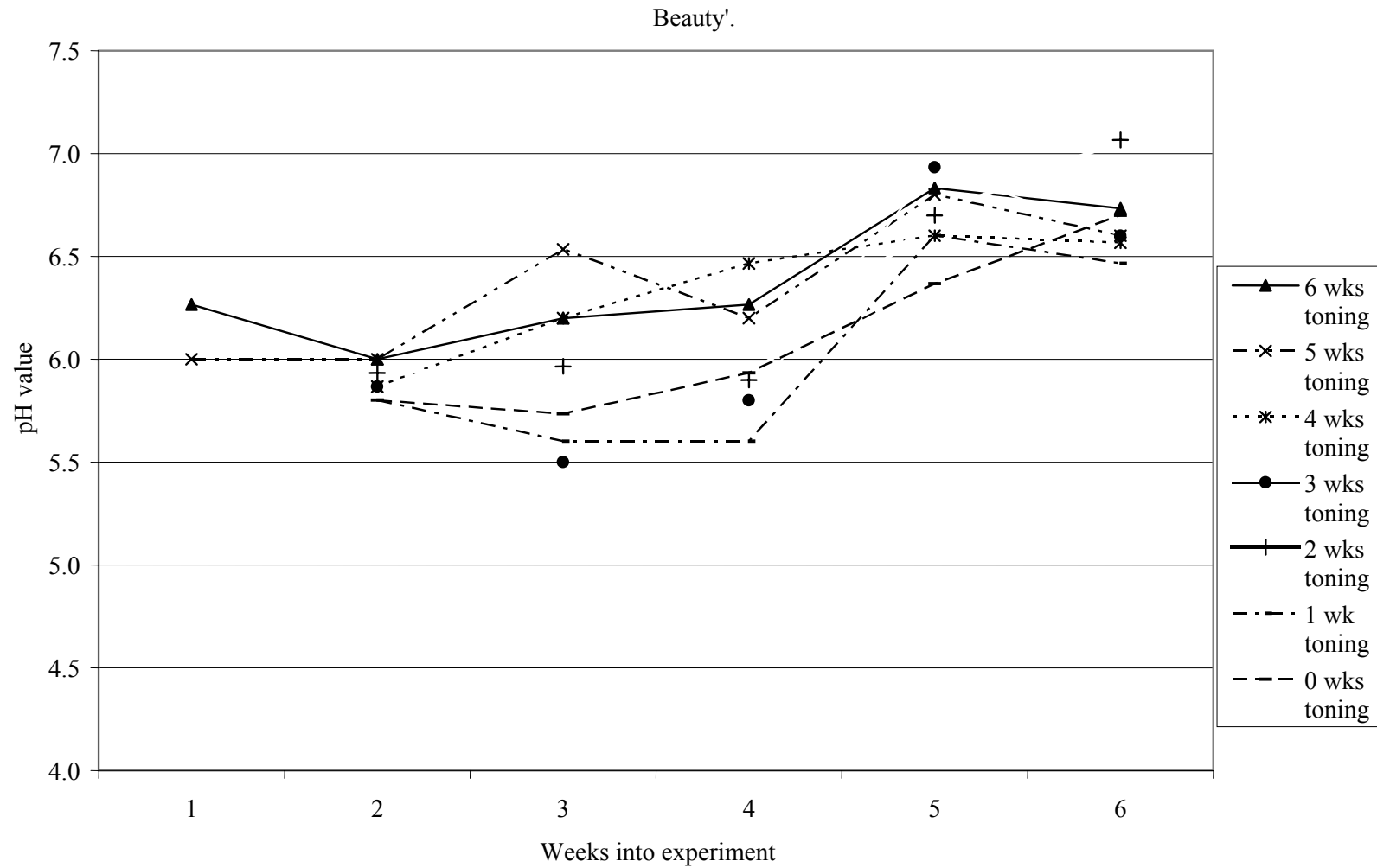


Fig. B-8. Effect of nitrogen toning on weekly average pH values on *Bracteantha bracteata* 'Sundaze Golden

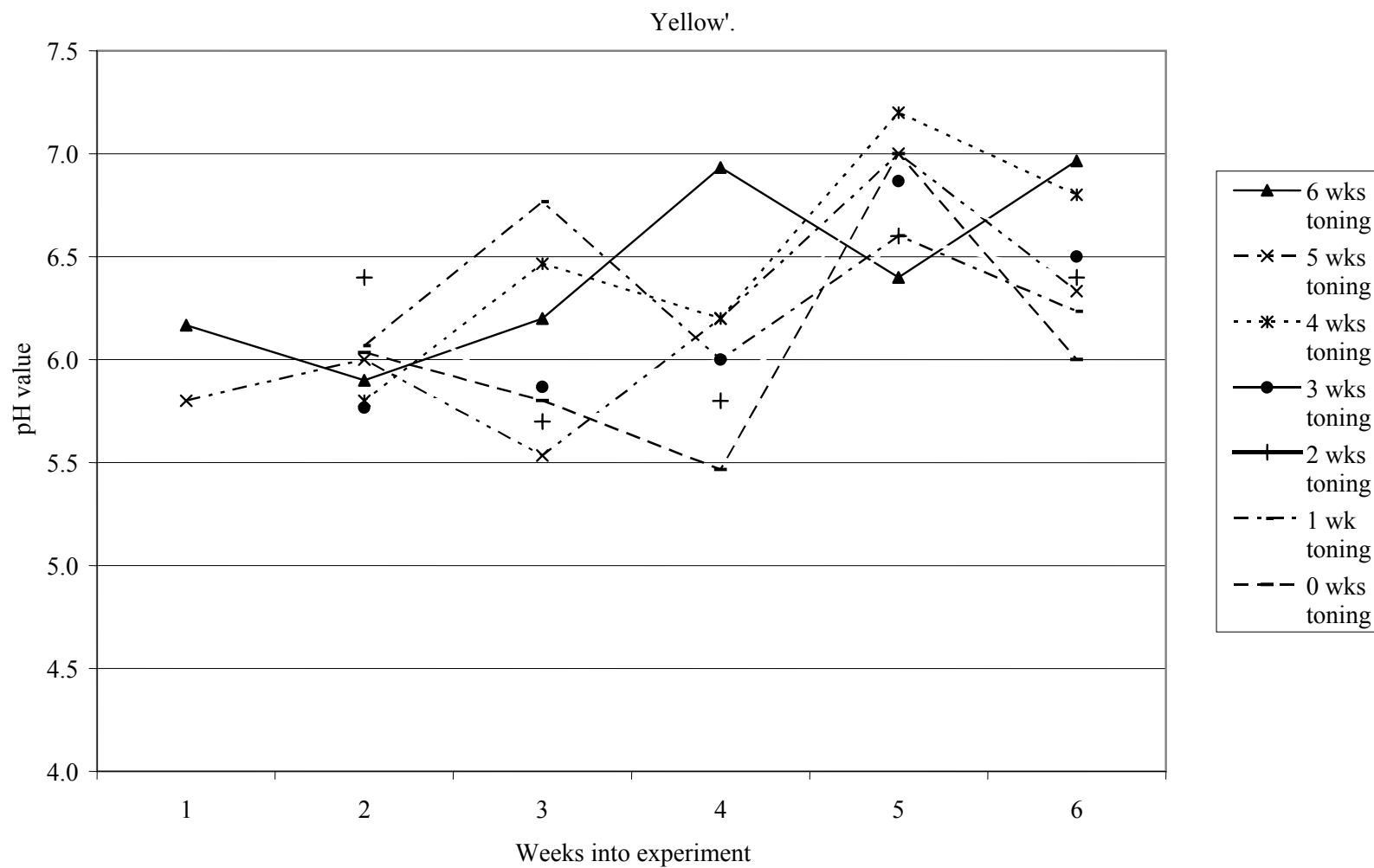


Fig. B-9. Effect of nitrogen toning on weekly average pH values on *Bracteantha bracteata* 'Sundaze Pink'.

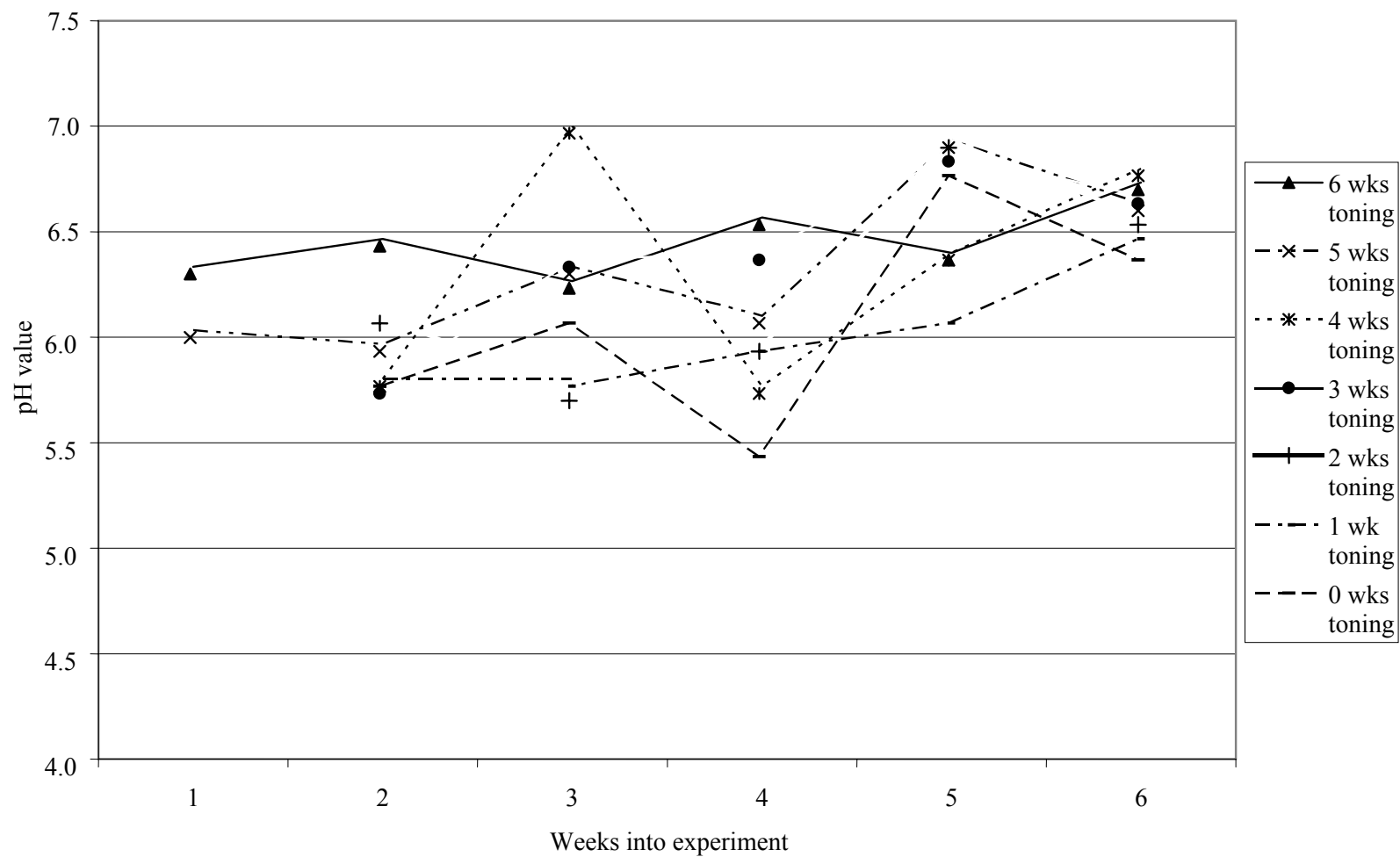
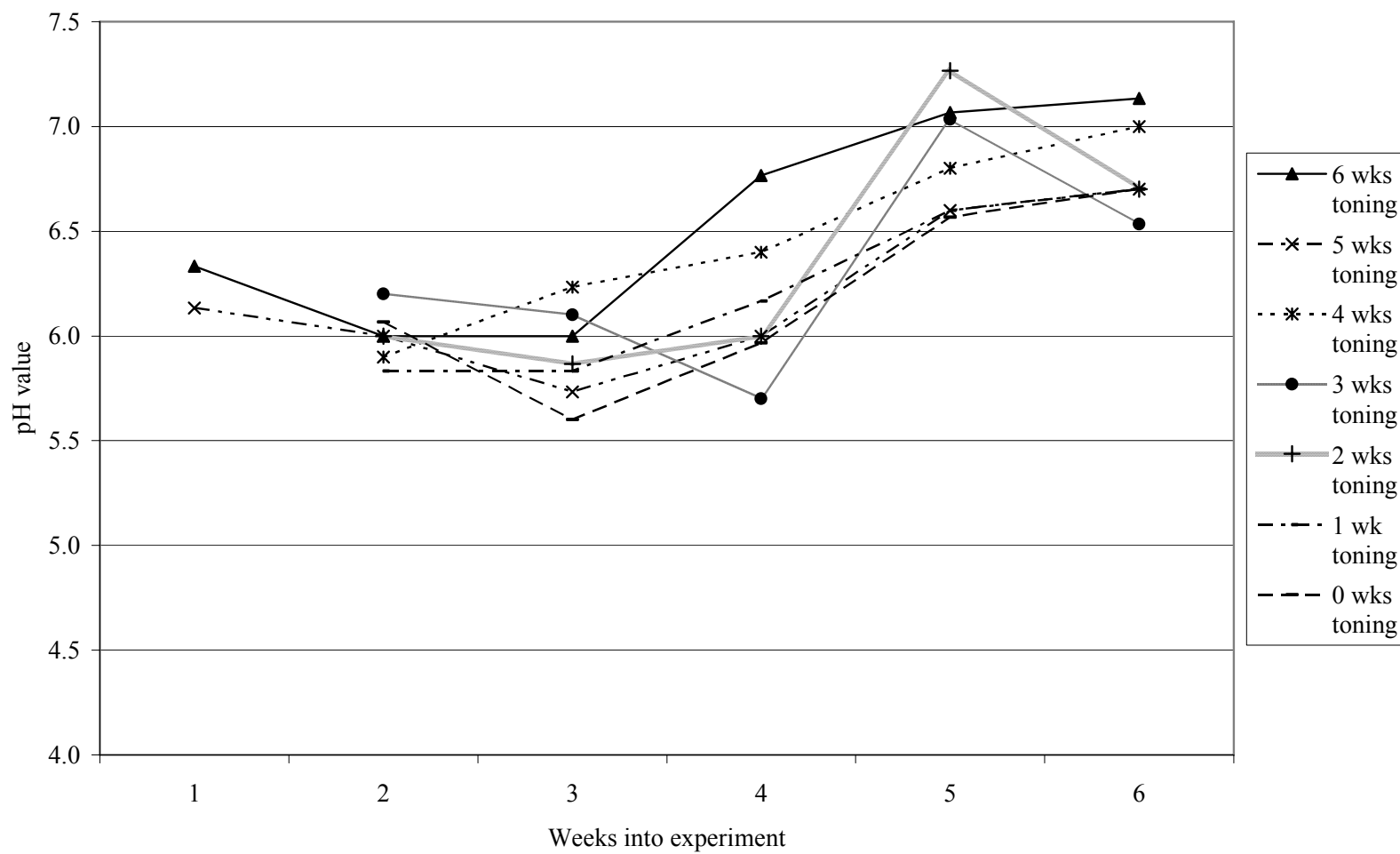


Fig. C-10. Effect of nitrogen toning on weekly average pH values on *Bracteantha bracteata* 'Sundaze White'.



APPENDIX C**PLANT GROWTH REGULATOR SCREENING ON POSTHARVEST QUALITY
OF VEGETATIVE ANNUALS**

Introduction

Plant growth regulators (PGRs) have many purposes. Some are used for growth control whether to promote growth or branching or to reduce internode elongation. Matsoukis et al. (2001) applied paclobutrazol, as a foliar spray to runoff, to *Lantana camara* L. at 0, 20, 40, 80, and 160 mg·L⁻¹. They found the growth index (mean of height and two widths) decreased as paclobutrazol concentration increased but flower number increased with increasing paclobutrazol concentrations. They also found the treated leaves were greener than the control plants. Application of 1 mg·L⁻¹ paclobutrazol as a drench to *Calibrachoa* hybrid ‘Mini-Famous Pink’ and ‘Mini-Famous Blue’ was found to reduce plant size by 12% to 15% five weeks post-treatment. Application of 8 mg·L⁻¹ was found to reduce plant size by 27% to 28% five weeks post-treatment (Berghauer et al., 2002).

Other PGRs are used to improve plant appearance or prolong postharvest life of the plant. Foliar applications of GA₄₊₇ plus BA at 100 mg·L⁻¹ prevented lower leaf chlorosis and increased flower longevity of *Lilium longiflorum* Thunb. (Ranwala et al., 2000). Thidiazuron (TDZ) was found to delay leaf chlorosis in *Alstromeria pelegrina* L. by more than two months when applied as a 24 h pulse treatment at a concentration ≥ 10 μ M. However, it did not prolong flower life (Ferrante et al., 2002). Serek et al. (1995) found application of 1-methylcyclopropene (1-MCP) at 20 nL·L⁻¹ on *Antirrhinum majus* L. improved vase life of flowers continuously kept in 1 μ L·L⁻¹ ethylene. *Dianthus caryophyllus* L. stems treated with nL·L⁻¹ 1-MCP lasted seven days compared to the control stems that lasted four days.

The objective of this research was to evaluate the effect of four PGRs on the postharvest life of nine species of vegetative annuals.

Materials and Methods

The plants were grown at the same time and in the same manner as described for experiment one.

TREATMENTS. One week prior to harvesting, (harvest defined as when plants were marketable, i.e. foliage covering the media and open flowers on the plant) plants were divided into nine treatment groups consisting of six (cool season) or four (warm season) plants per cultivar per treatment. The nine treatment groups were treated with one of four plant growth regulators at one of two rates. The growth regulators used were thidiazuron [N-phenyl-N'-(1,2,3-thidiazol-5'yl urea), Dropp 50WP, Aventis CropScience USA, Research Triangle Park, NC] at 0.1 and 1.0 mg·L⁻¹; BA + GA₄₊₇ {[N-(phenylmethyl)-1H-purine 6-amine] plus Gibberellins A₄A₇; Fascination, Valent, USA, Marysville, OH} at 2.75 and 5.5 mg·L⁻¹; 1-MCP (1-Methylcyclopropene, Ethylbloc, Floralife, Waterboro, SC) at 396 and 792 mg·L⁻¹; and paclobutrazol {[B-[(4-chlorophenyl)methyl]-α-(1,1-dimethyl)-1*H*-1,2,4-triazole-1-ethanol]; Bonzi; Uniroyal Chemical, Middlebury, Conn.} at 1.25 and 2.50 mg·L⁻¹. The ninth group was the control and received no treatment. Paclobutrazol was applied as a drench, all other growth regulators were applied as a foliar spray to runoff.

POSTHARVEST. At harvest, digital photographs were taken of all treatments and cultivars and visual observations were made. Following this, two plants per cultivar per treatment

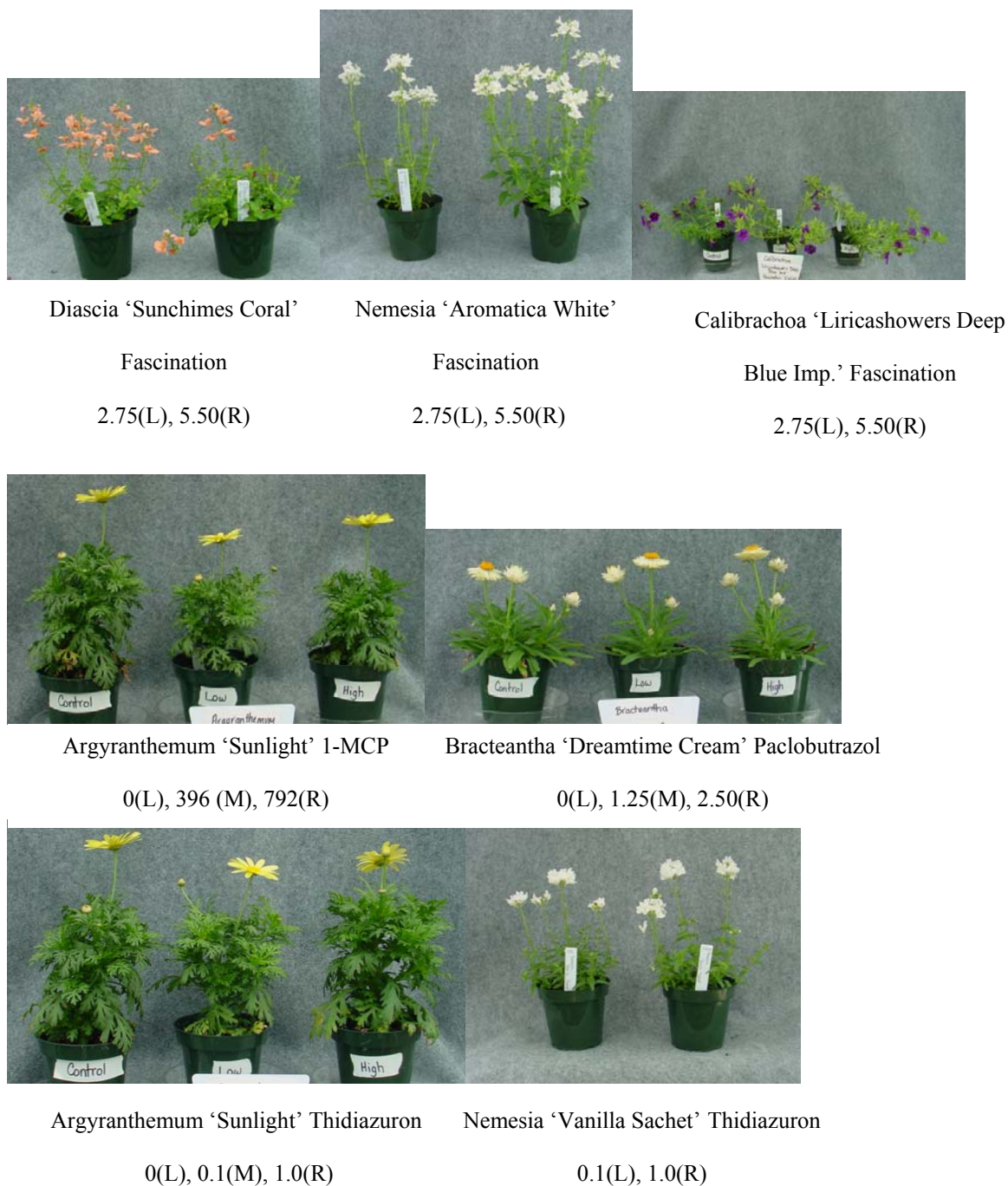
were moved directly to a growth room and the remaining plants (two or four plants season dependent) stayed in the greenhouse. The growth room was set at 21.1 ± 1.3 °C (Appendix Fig A-8) with an average light intensity of $6 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. Plants remained in the growth room for three weeks where weekly observation was taken and comparisons to the control plants were made.

Results

Chemicals caused consistent responses in all species and cultivars. Fascination caused extreme internode elongation on treated plants. Thidiazuron reduced peduncle elongation in nemesia creating a “clubby” flower raceme. Little growth response was noted on the 1-MCP or paclobutrazol treated plants at harvest. After two weeks postharvest it appeared the paclobutrazol treated plants had greater longevity than the other treatments. The 1-MCP plants did not appear to have any differences from the control plants. Thidiazuron treated plants appeared to have decreased leaf chlorosis when compared to the control plants.

Fig. C-1. Plant growth regulator effects on vegetative annual species at harvest.

Concentrations ($\text{mg}\cdot\text{L}^{-1}$), (L)= left, (M)= middle, and (R)= right.



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Beach, S.E., T.W. Starman, and H.B. Pemberton. 2004. Nitrogen toning and thidiazuron (TDZ) improve pot plant quality of *Bracteantha bracteata* cultivars. American Society for Horticultural Sciences at Austin, TX, July 2004 (oral presentation).

Posters Presented at Professional Meetings

Beach, S.E. and T.W. Starman. 2004. Shipping and 1-methylcyclopropene (1-MCP) effects on shelf life of *Diascia Xhybrida*. American Society for Horticultural Sciences at Austin, TX, July 2004 (poster).

Beach, S.E. and T.W. Starman. 2004. Characterization of postharvest disorders and the effect of shipping on shelf life of 22 vegetative annual cultivars. American Society for Horticultural Sciences at Austin, TX, July 2004 (poster).

Beach, S.E., J.M. Coons, H.R. Owen, B.L. Todd, and M.A.L. Smith. 2002. Seed vigor of *Lesquerella ludoviciana* as affected by colony and maturity. Trans. Ill. State Acad. Sci. 95: 82. (abstr.).